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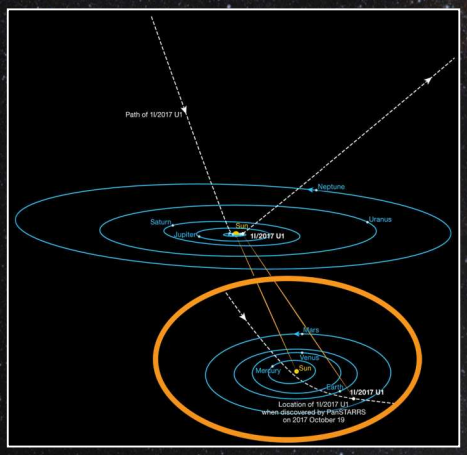
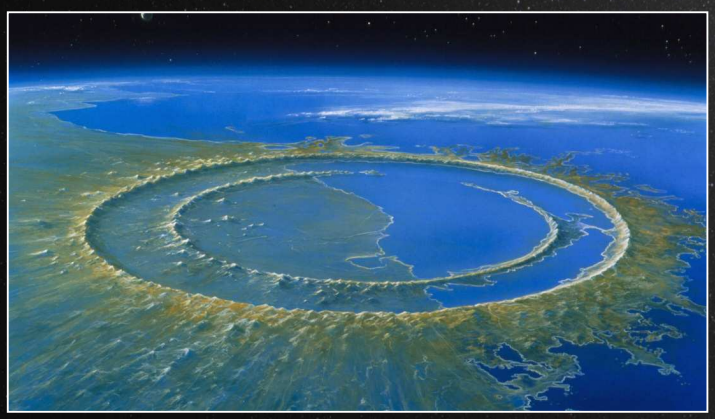


The first interstellar asteroid

Chicxulub: perfect timing... for us!



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BI-MONTHLY MAGAZINE OF SCIENTIFIC AND TECHNICAL INFORMATION FREELY AVAILABLE THROUGH THE INTERNET

January-February 2018

English edition of the magazine

ASTROFILO

Editor in chief
Michele Ferrara

Scientific advisor
Prof. Enrico Maria Corsini

Publisher
Astro Publishing di Pirlo L.
Via Bonomelli, 106
25049 Iseo - BS - ITALY
email info@astropublishing.com

Internet Service Provider
Aruba S.p.A.
Via San Clemente, 53
24036 Ponte San Pietro - BG - ITALY

Advertising - Administration
Astro Publishing di Pirlo L.
Via Bonomelli, 106
25049 Iseo - BS - ITALY
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SUMMARY

The first int asteroid

by Michele Ferrara

Our current technology does not allow us to reach other planetary systems, and this limitation will remain for a long time. This will not prevent us, however, from closely studying asteroids and comets born light years away around stars other than the Sun. The first of those objects has already been discovered a short distance from our planet, and we are thinking about how to intercept the next one.

erstellar

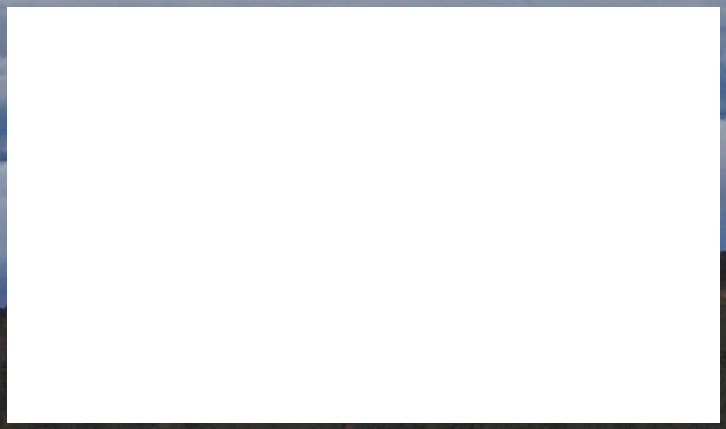
This artist's impression shows the first interstellar asteroid: Oumuamua. This unique object was discovered by the Pan-STARRS 1 telescope in Hawaii. [ESO/M. Kornmesser]

In astronomy, each discovery adds a piece to the great puzzle of the universe. A century ago, we thought our galaxy represented the whole cosmos. Thirty years ago, we could only imagine there were planets around other stars, and interstellar space was always considered empty or, at best, just filled with a few atoms of gas per cubic meter. To tell the truth, as early as the 1930s, on several occasions, someone hypothesized the existence of numerous dark bodies of various sizes in free movement in the empty spaces separating the stars. Verifying the hypothesis seemed difficult, as these bodies did not emit enough radiation to be distinguished from the black background of the night sky. In the last twenty years, however, exploitation of what is called

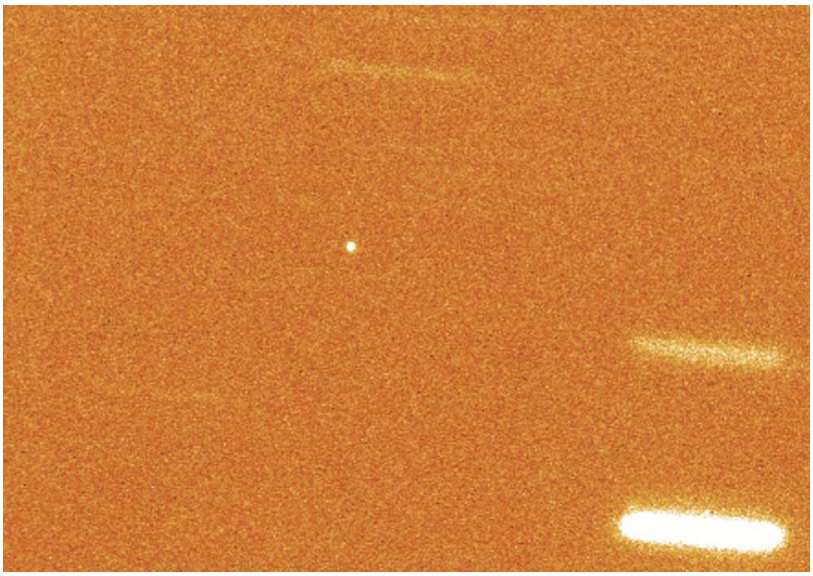
microlensing (an increase in the light from a background star following the transit of a dark body in front of it) has allowed us to close that gap, revealing the existence of sub-stellar and planet-sized objects wandering the galaxy. About fifteen of these bodies are known today, and the presence of many others is suspected. Conservative assessments indicate that their total number is twice the number of stars in the Milky Way, and thus some hundreds of billions. Despite this enormous amount, the galaxy is so gigantic that the population of large objects is hugely dispersed. While it is true that, when it comes to sub-stellar and planetary sized objects, interstellar space is essentially empty, the same conclusion may not be valid for smaller bodies, the number of which increases exponentially

The Pan-STARRS1 Observatory on Halealakala, Maui, opens at sunset to begin a night of mapping the sky. [Rob Ratkowski]

as the size decreases. In this case, we refer to asteroids and comets, whose presence in interstellar space is also indicated by the most reliable models of planetary system formation. These models predict that the stages of formation and migration of planets within each system are responsible for the expulsion of countless billions of rocky and icy bodies, which in escaping the gravitational attraction of their stars would end up wandering through the galaxy indefinitely. It is estimated that, on average, any existing planetary system may have ejected the equivalent of approximately 20 Earth masses in the form of asteroids and comets. Considering that, as far as we know today, the majority of stars possess planetary systems, it goes without saying that there is a multitude of objects around the galaxy whose presence could only be revealed if they were close enough to be within reach of our most efficient photographic telescopes. Researchers have calculated how many asteroids or comets expelled from other planetary systems we should be able to discover every year, and the result is 0.2, or one every five years on average. This assessment is inevitably approximate since the variables in the equation are so numerous that this calculation seems a mere probabilistic exercise. Nevertheless, a surprising thing happened last October, which in all respects appears to confirm that hypothetical scenario. Here are the facts.



Oumuamua spotted whizzing through the Solar System in images taken with the WIYN telescope. The faint streaks are background stars. The green circles highlight the position of the asteroid in each image. In these images Oumuamua is about 10 million times fainter than the faintest stars visible with the naked eye.
[R. Kotulla (University of Wisconsin) & WIYN/NOAO/AURA/NSF]



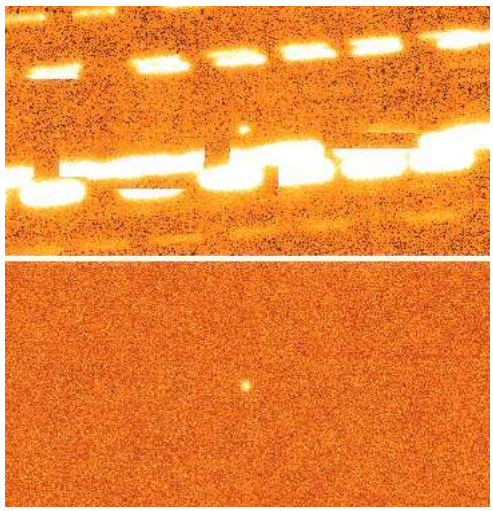
Oumuamua in a 300-second false-colour image taken on Oct. 29 from Gemini Observatory on Mauna Kea, Hawaii. [Gemini Observatory, NSF, AURA /M. T. Bannister, R. E. Pike, M. E. Schwamb] Below, multiple exposures centered on Oumuamua combined into one image. [R. Kotulla (University of Wisconsin) & WIYN/NOAO/AURA/NSF]

At the end of the day on October 19, Rob Weryk, a postdoctoral researcher at the University of Hawaii Institute for Astronomy (IfA), was looking at images taken hours earlier by the Panoramic Survey Telescope and Rapid Response System 1 (PanSTARRS 1), a 1.8-meter diameter telescope dedicated to the search for potentially dangerous asteroids. Weryk noticed a luminous track in the Pisces constellation made by an object of about magnitude 20. Excited by what he saw, he examined images from the previous night and found the track on those too, but in an area of the sky so different that it had not been signalled by the automatic system detecting moving objects.

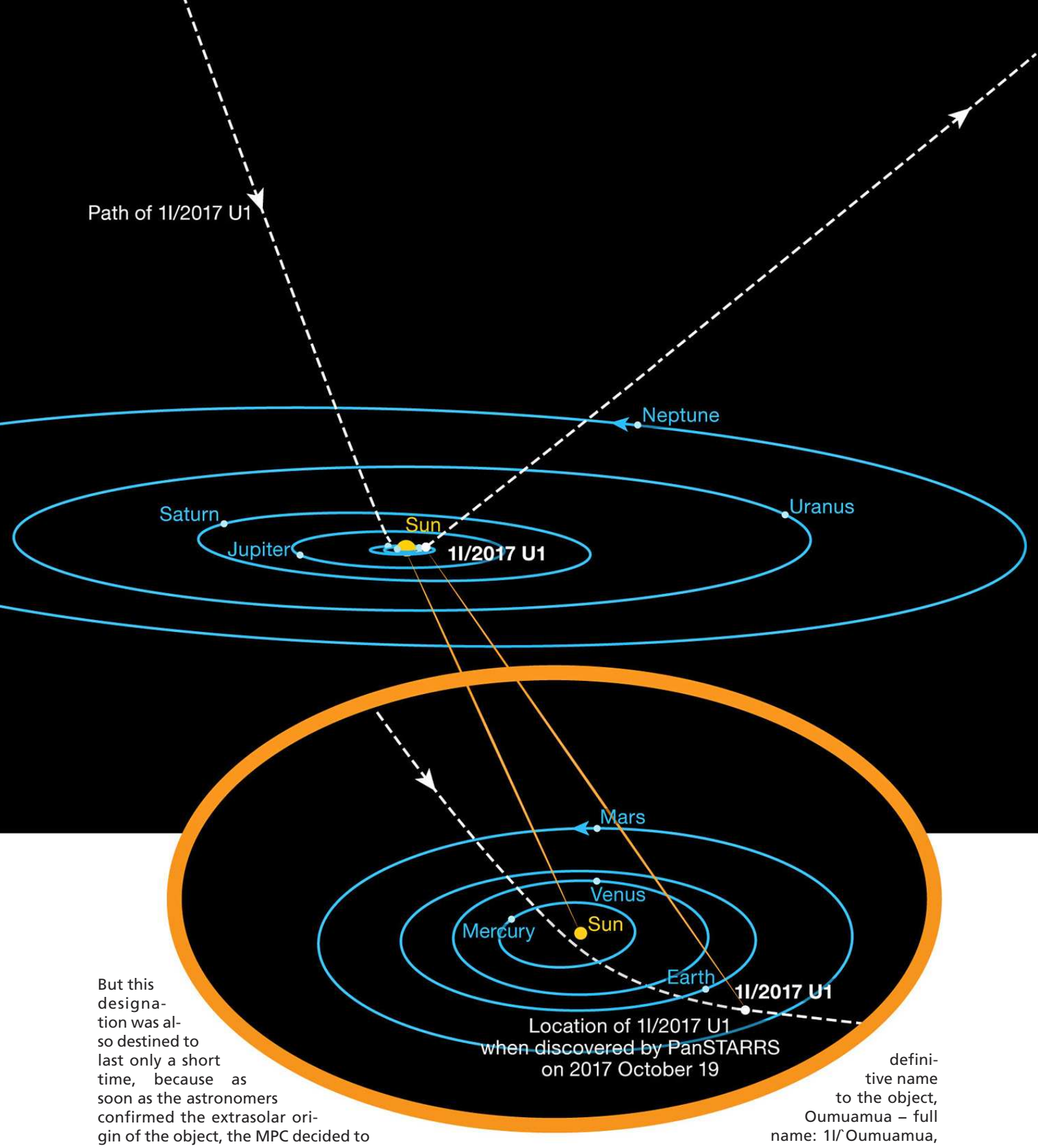
At that point, Weryk contacted a specialist in the field, Marco Micheli, of the Instituto de Astrofísica de Canarias (a former IfA researcher), who confirmed the presence of the object through observations conducted with the 1-meter telescope at the ESA's Optical Ground Station in Tenerife.

The preliminary calculation of the mysterious object's trajectory provided a surprising datum: the eccentricity of its orbit is close to 1.2. When eccentricity is greater than 1, we are dealing with a hyperbolic trajectory, that of a body that does not orbit around the Sun. Weryk and Micheli soon realized that that object came from outside our solar system. This unique opportunity to study a body formed in another planetary system mobilised numerous researchers, and within a few hours many telescopes, including larger ones, were aimed at the 'visitor'.

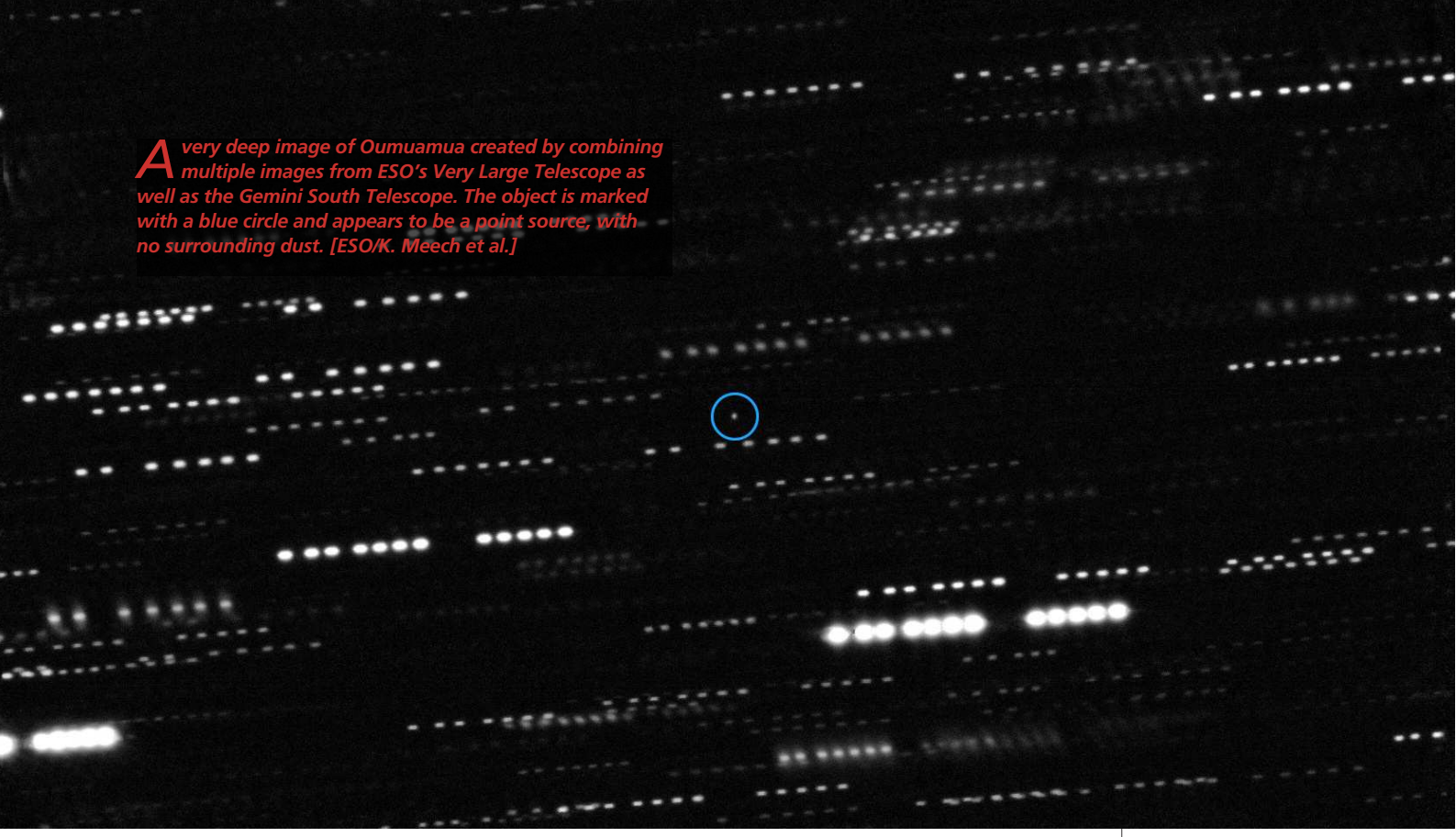
Since it initially appeared to be a cometary nucleus, the object was recorded by the Minor Planet Center (MPC, Cambridge, Massachusetts) under the name C/2017 U1. However, the most in-depth images taken with the ESO's Very Large Telescope (8.2-meter) soon showed that there was no trace of cometary activity and therefore the interloper could only be an asteroid, so the designation changed to A/2017 U1.



Above and following page, this diagram shows the orbit of the interstellar asteroid Oumuamua as it passes through the Solar System. Unlike all other asteroids and comets observed before, this body is not bound by gravity to the Sun. It has come from interstellar space and will return there after its brief encounter with our star system. Its hyperbolic orbit is highly inclined and it does not appear to have come close to any other Solar System body on its way in. [ESO/K. Meech et al.]



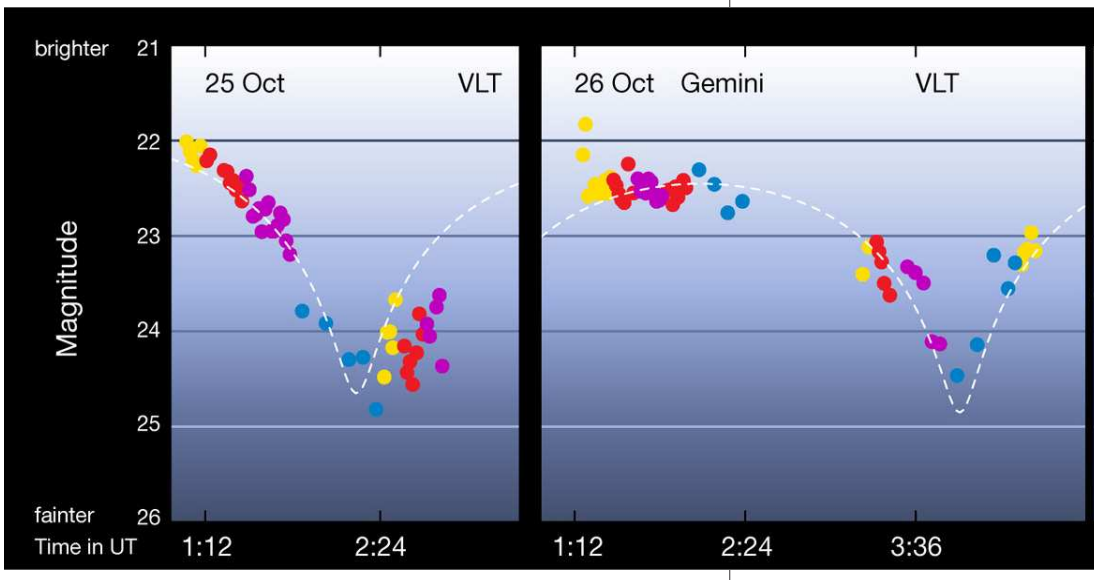
But this designation was also destined to last only a short time, because as soon as the astronomers confirmed the extrasolar origin of the object, the MPC decided to introduce a new class, the I class (for interstellar), and the provisional name of the object became I/2017 U1. Finally, with unprecedented speed, the MPC and the Working Group on Small Body Nomenclature of the International Astronomical Union decided to assign a definitive name to the object, Oumuamua – full name: 1I/`Oumuamua, pronounced *'oh-moo-ah-moo-ah'* and meaning *'a messenger from afar arriving first'* in Hawaiian. In the first two weeks after the discovery, at least a dozen teams of researchers participated in the dynamic, photometric and spectroscopic study of



A very deep image of Oumuamua created by combining multiple images from ESO's Very Large Telescope as well as the Gemini South Telescope. The object is marked with a blue circle and appears to be a point source, with no surrounding dust. [ESO/K. Meech et al.]

Oumuamua. In record time, several articles were submitted to scientific journals in which the first conclusions were drawn, as briefly summarised below.

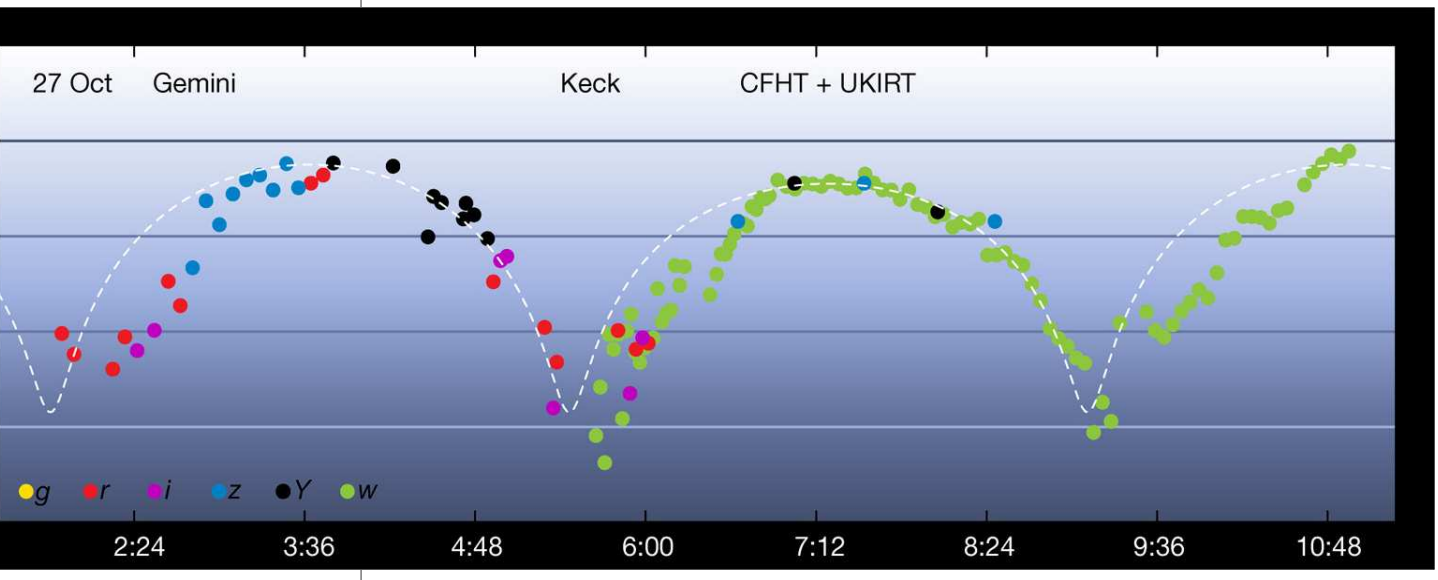
Oumuamua entered the solar system from above, from a very high point on the plane of the ecliptic (about 123°); on September 2 it dropped below the ecliptic, just inside the orbit of Mercury, and on September 9 it transited to its shortest distance from Sun, 37.6 million km, where its surface probably reached a temperature higher than 550 K, assuming an albedo of 5%. Its travel speed, estimated at 26 km/s, rose to 88 km/s during its passage to the periastron, when the Sun's gravity dramatically altered the object's trajectory. Indeed, Oumuamua's course bent sharply, climbing towards the ecliptic at a less steep angle than during its arrival, leading it in the direction of Earth, which it neared on October 14 at a distance of 24 million km and at a speed of 44 km/s. Four days later, Oumuamua was discovered, and once its distance was known, its approximate diameter, 100-300 meters, could be calculated – depending on the surface reflectivity adopted in the calculation. Accurate photometric observations made with the 4.3-meter Discovery Channel Telescope at the Lowell Observatory (Flagstaff, Arizona), allowed the tracing of a light curve with a variability of at least 1.2 magnitudes and a rotation period of not less than 3 hours, but probably greater than 5 hours. Assuming that the variability is due to the shape of Oumuamua, researchers estimated a ratio of 3:1 between its major axis and its minor axis. Different results have come from other researchers, led by well-known specialist David Jewitt of UCLA. Five nights using the



Below, Oumuamua variations in brightness during three days in October 2017. The large range of brightness is due to the very elongated shape of this unique object. The different coloured dots represent measurements through different filters, covering the visible and near-infrared part of the spectrum. The dotted line shows the light curve expected if Oumuamua were an ellipsoid with a 1:10 aspect ratio. [ESO/K. Meech et al.]

A brief overview of the discovery of the first interstellar asteroid. [ESO]

3.5-meter WIYN Telescope at the Kitt Peak National Observatory and the 2.5-meter Nordic Optical Telescope in La Palma, Canary Islands, revealed an 8-hour rotation period and a ratio of 6:1 between the axes, for a real dimension of about 180x30x30 meters. Even more extreme is the ratio between the axes obtained by a team of astronomers led by Karen Meech (IfA).
Combining images taken by the VLT's FORS (FOcal Reducer and low dispersion Spectrograph) with data produced by other observatories, they concluded that Oumuamua is at least 400 meters long and only one-tenth as wide, that it turns on its axis in 7.3 hours and that it has a very dark red surface. This peculiarity is compatible with a long stay in interstellar space (perhaps billions of years) and is virtually the only information provided by spectroscopic observations, despite the spectra being acquired by other big telescopes as well,



such as the 5-meter telescope on Mount Palomar (the Hale Telescope) and the 4.2-meter telescope on Roque de los Muchachos, Canary Islands (the William Herschel Telescope).

It is interesting to note that Oumuamua entered our solar system from a point in space just 6° from what is called the solar apex, i.e., the apparent direction in which the Sun and its system are moving (at about 250 km/s). It is statistically more likely that an extrasolar object would arrive from that direction and, if it originated with and was expelled by a relatively close star, it is equally likely it would travel at a speed of 20 to 30 km/s. Since Oumuamua's arrival speed is almost centred in that range, some researchers have pointed to some possible asteroid parent stars, all of which are relatively close star associations, such as the Scorpius-Centaurus association, the Carina association, the Columba association and the Tucana-Horologium association. It is actually impossible to establish from which planetary system Oumuamua was initially expelled because, before coming to us, it may have had previous close transits with other stars, which would have

Artist's impression of Oumuamua. Observations from ESO's VLT and other telescopes around the world show that this unique object was travelling through space for millions of years before its chance encounter with our star system. [ESO/ M. Kornmesser]

At the top right, an animation showing the path of Oumuamua through the solar system. Observations made with the ESO VLT and other telescopes have shown that this single object is dark, reddish and very elongated. [ESO, M. Kornmesser, L.Calcada. Music: Azul Cobalto]

dramatically changed its trajectory (there are 357 stars within 10 parsecs of the Sun).

If in the future an inhabitant of a distant exoplanet should see Oumuamua (it is heading towards the Pegasus constellation), it would appear to be coming from the direction of the Sun, but it only made a brief appearance here – though it will take it several years to permanently exit the solar system.

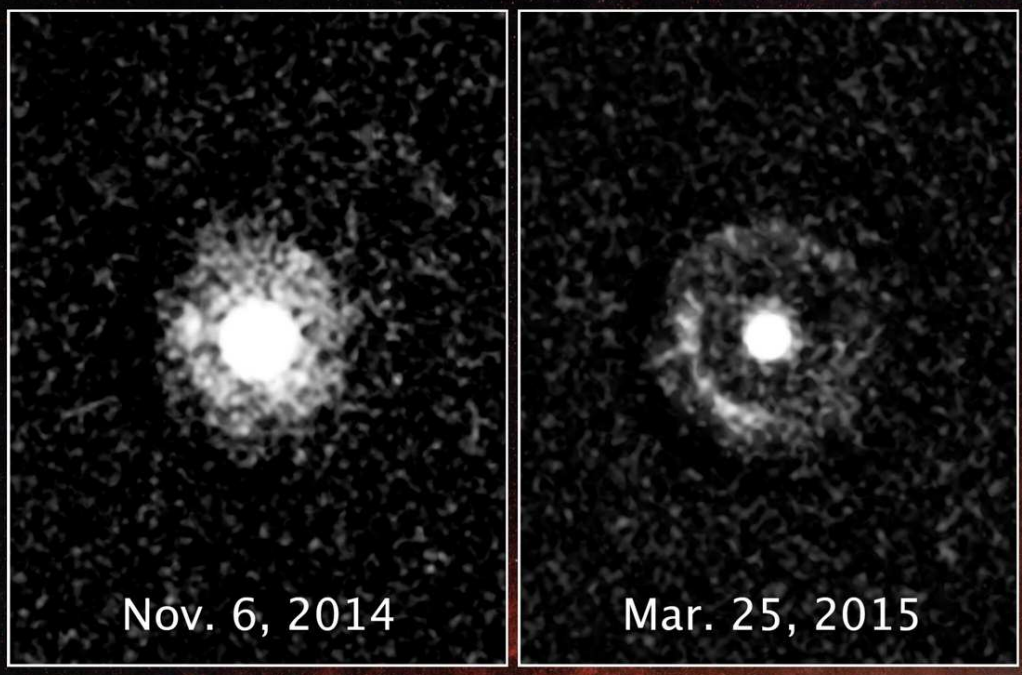
Although Oumuamua's origins will remain a mystery, we know for sure that in astronomical terms it has passed extremely close to the Sun, so much so that no one would ever have expected such an event. The most optimistic predictions indicated that, depending on the power of the telescopes used, the first object of that type would probably be discovered at a distance from the Sun of 10 to 30 astronomical units, thus in a much larger volume of space. Having found it so close to the Sun and the Earth could mean either that there are more of such visitors than expected or that we were very lucky this time.

Undoubtedly, the discovery of Oumuamua opens a new research path that will have significant repercussions on theories on the formation and evolution of planetary systems, as well as on our knowledge of the matter they disperse within our galaxy.

It is easy to forecast that in the coming years, with the most powerful photographic telescopes in the world, such as PanSTARRS 1, its recent twin PanSTARRS 2, the Catalina Sky Survey (0.5- to 1.5-meter telescopes), the Visible and Infrared Survey Telescope for Astronomy (VISTA, 4.1 meters) and the Large Synoptic Survey Telescope (LSST, 8.4 meters, beginning operation in 2021), astronomers will be able to discover a growing number of interstellar visitors. It is expected that the LSST will allow us to find, on average, one new object per year.

When a statistically significant number have been discovered, we will know whether there are more asteroids or more comets among them.

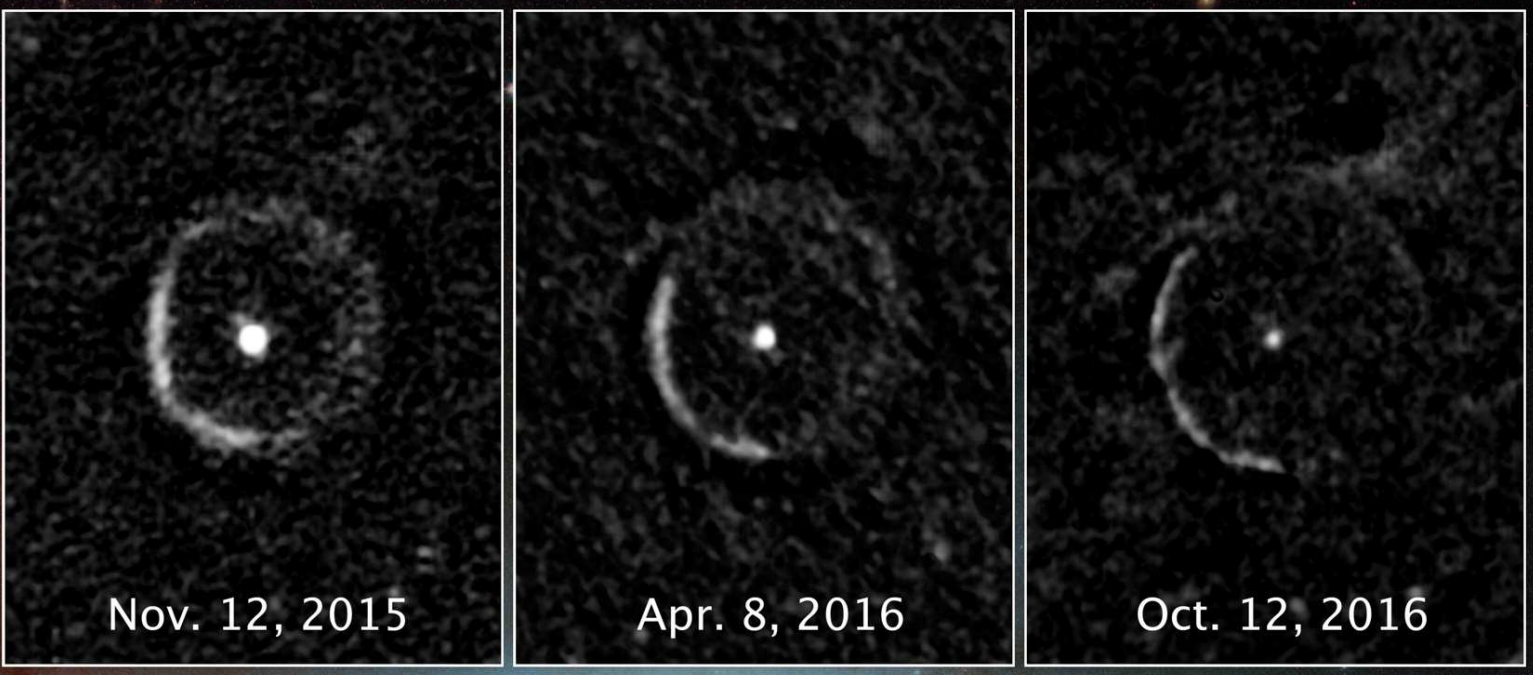
Since the giant planets are mainly responsible for expelling those objects from planetary systems, a predominance of rocky and iron-bearing asteroids will mean that systems with giant planets very close to their stars are more common; on the other hand, a prevalence of icy cometary nuclei could tell us that the maximum expulsion of objects occurs at great distances from the stars, where cold volatiles are much more abundant and persistent. ■



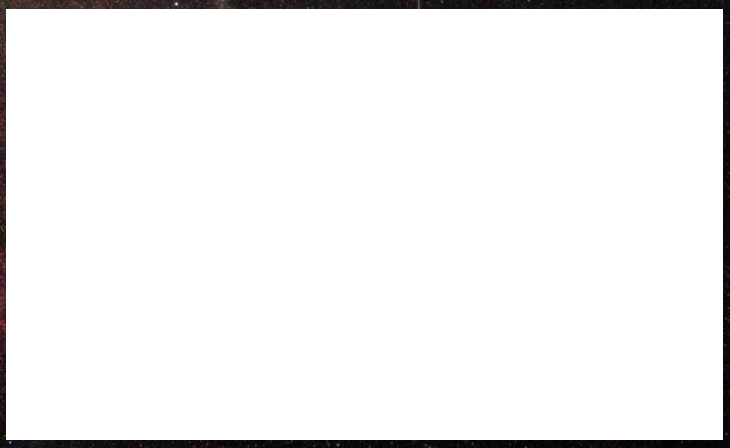
Movement of light echo around SN 2014J in M82

by NASA

Voices reverberating off mountains and the sound of footsteps bouncing off walls are examples of an echo. Echoes happen when sound waves ricochet off surfaces and return to the listener. Space has its own version of an echo. It's not made with sound but with light, and occurs when light bounces off dust clouds. The Hubble telescope has just captured one of these cosmic echoes, called a "light echo," in the nearby starburst galaxy M82, located 11.4 million light-years away. A movie assembled from more than two years' worth of Hubble images reveals an expanding shell of light from a supernova explosion sweeping through interstellar space three years after the stellar blast was discovered. The "echoing" light looks like a ripple expanding on a pond. The supernova, called SN 2014J, was discovered on Jan. 21, 2014. A light echo occurs because light from the stellar blast travels different distances to arrive at Earth. Some light comes to Earth directly from the supernova blast. Other light is delayed because it travels indirectly. In this case, the light is bouncing off a huge dust cloud that extends 300 to 1,600 light-years around the supernova and is being reflected toward Earth. So far, astronomers have spotted only 15 light echoes around supernovae outside our Milky Way galaxy. Light echo detections from supernovae are rarely seen because they must be nearby for a telescope to resolve them. ■



Light from a supernova explosion in the nearby starburst galaxy M82 is reverberating off a huge dust cloud in interstellar space. The supernova, called SN 2014J, occurred at the upper right of M82, and is marked by an "X." The supernova was discovered on Jan. 21, 2014. The inset images at top reveal an expanding shell of light from the stellar explosion sweeping through interstellar space, called a "light echo." The images were taken 10 months to nearly two years after the violent event (Nov. 6, 2014 to Oct. 12, 2016). The light is bouncing off a giant dust cloud that extends 300 to 1,600 light-years from the supernova and is being reflected toward Earth. The image of M82 reveals a bright blue disk, webs of shredded clouds, and fiery-looking plumes of glowing hydrogen blasting out of its central regions. [NASA, ESA, and Y. Yang (Texas A&M University and Weizmann Institute of Science, Israel)]

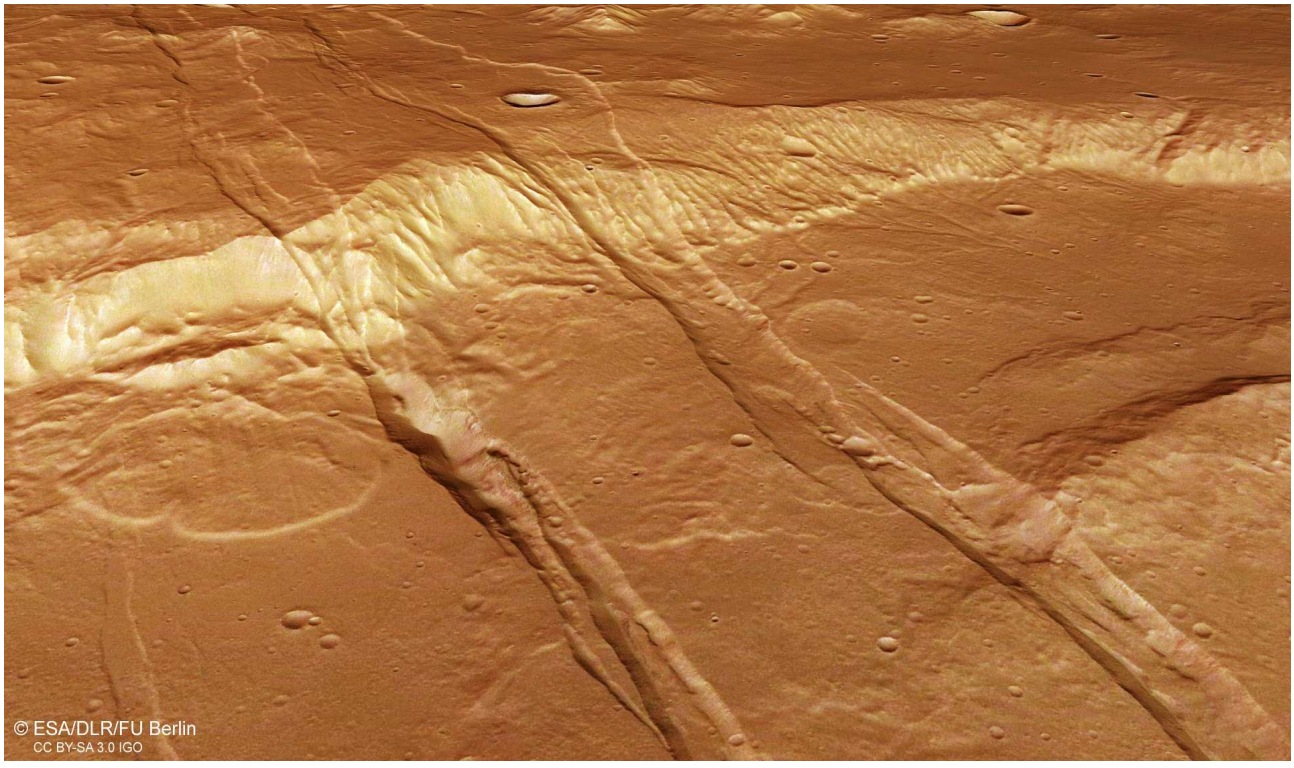


This video sequence takes the viewer into the nearby starburst galaxy M82, where a shell of light surrounding an exploding star is moving through interstellar space. [NASA, ESA, G. Bacon, J. DePasquale, and Z. Levay (STScI)]

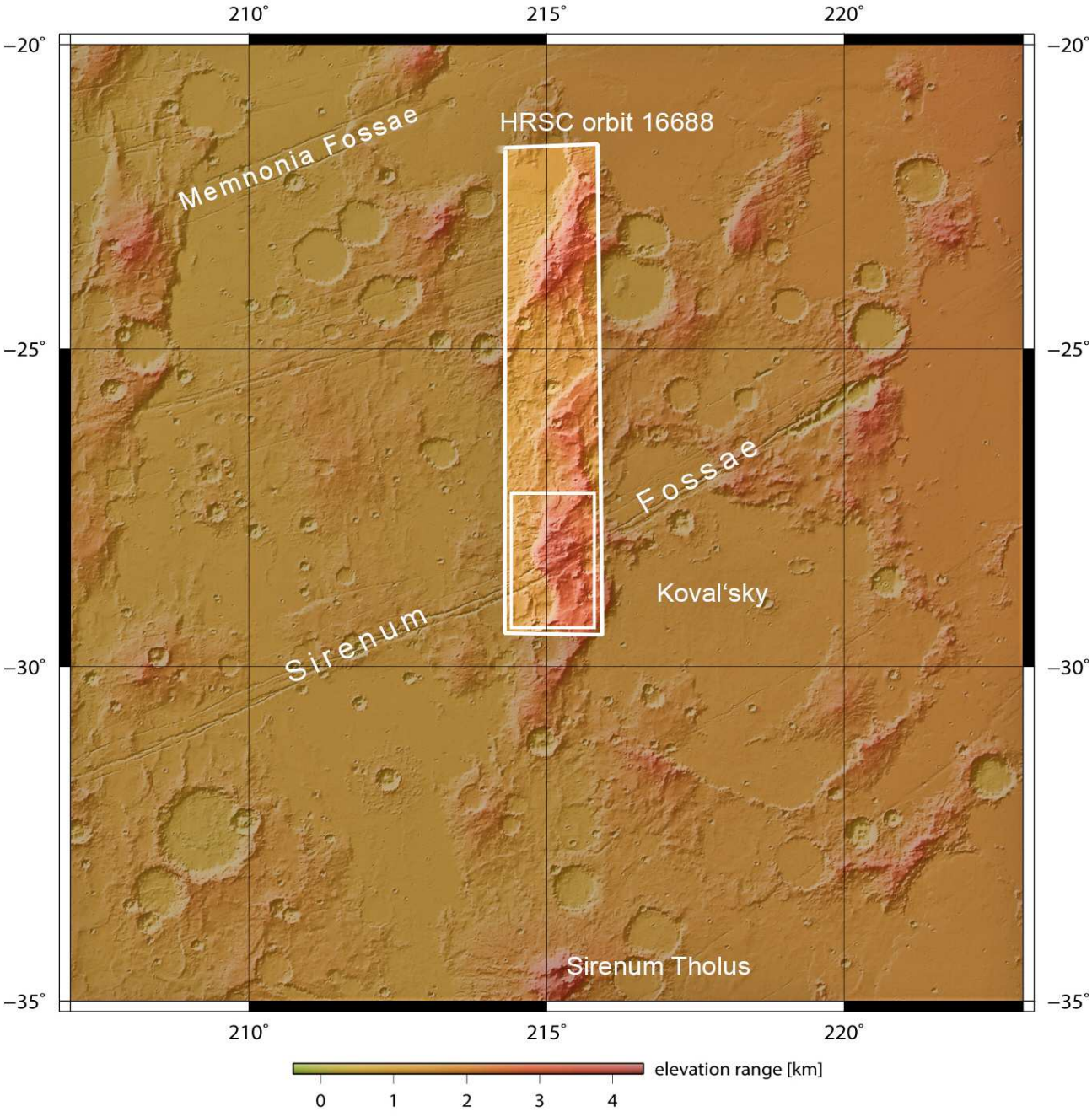
Fracture swarms on Mars

by ESA

These striking features on Mars were caused by the planet's crust stretching apart in response to ancient volcanic activity. The fractures in the Sirenum Fossae region in the southern hemisphere were imaged by ESA's Mars Express in March. They extend for thousands of kilometres in length, far beyond the boundaries of this image. The fractures divide the crust into blocks: the movement along a pair of faults causes the centre section to drop down into 'graben' several kilometres wide and a few hundred metres deep. Elevated blocks of crust remain between the graben when there is a parallel series of fault, as seen in this scene. The Sirenum Fossae are part of a larger radial fracture pattern around the Arsia Mons volcano in the Tharsis region, which is situated some 1800 km to the northeast. Tharsis is the largest vol-



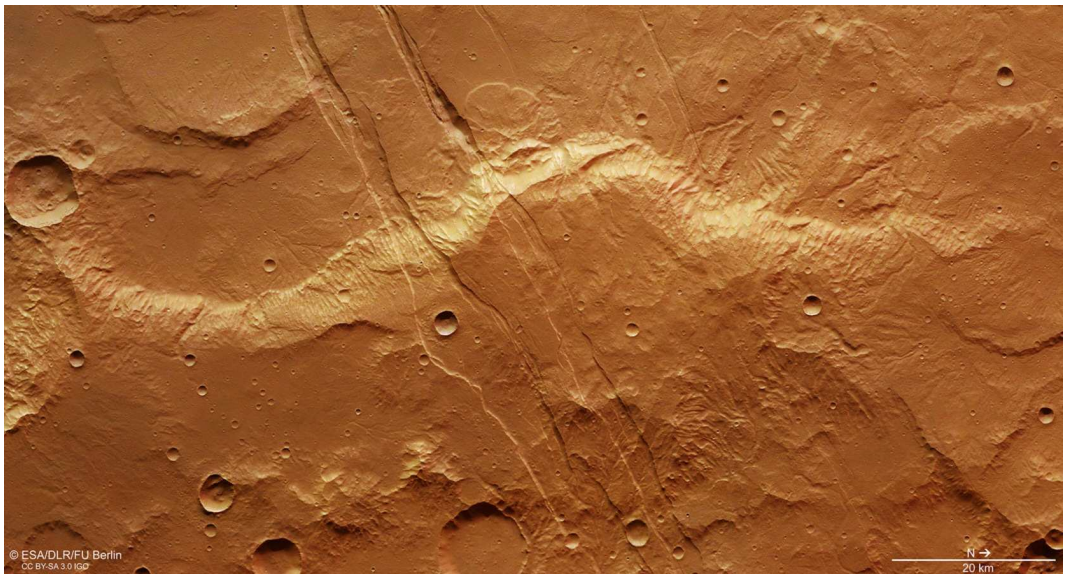
Perspective view of fractures in Sirenum Fossae in the southern hemisphere of Mars. The view shows the movement of the crust, likely in response to the tectonic stresses linked to volcanic activity of the wider region. In this kind of scenario, fractures divide the crust into blocks: movement along a pair of faults causes the centre section to drop down into 'graben'. The scene is part of the region imaged on 5 March 2017 during Mars Express orbit 16688. The ground resolution is about 14 m/pixel and the images are centred at 28°S / 215°E. North is to the right. [ESA/DLR/FU Berlin, CC BY-SA 3.0 IGO]



canic province on Mars, its far-reaching fracture system testament to the powerful influence this impressive volcanic province had on the planet. Indeed, the Sirenum Fossae fracture system seen here is thought to be associated with tectonic stresses arising from ancient volcanic activity in the Tharsis region. For example, the graben could either be caused by the planet's crust stretching apart as a magma chamber bulges the crust above it, or alternatively as the crust collapsed along lines of weakness as

The region outlined by the larger white box indicates the area imaged during Mars Express orbit 16688 on 5 March 2017. [NASA MGS MOLA Science Team, Freie Universitaet Berlin]

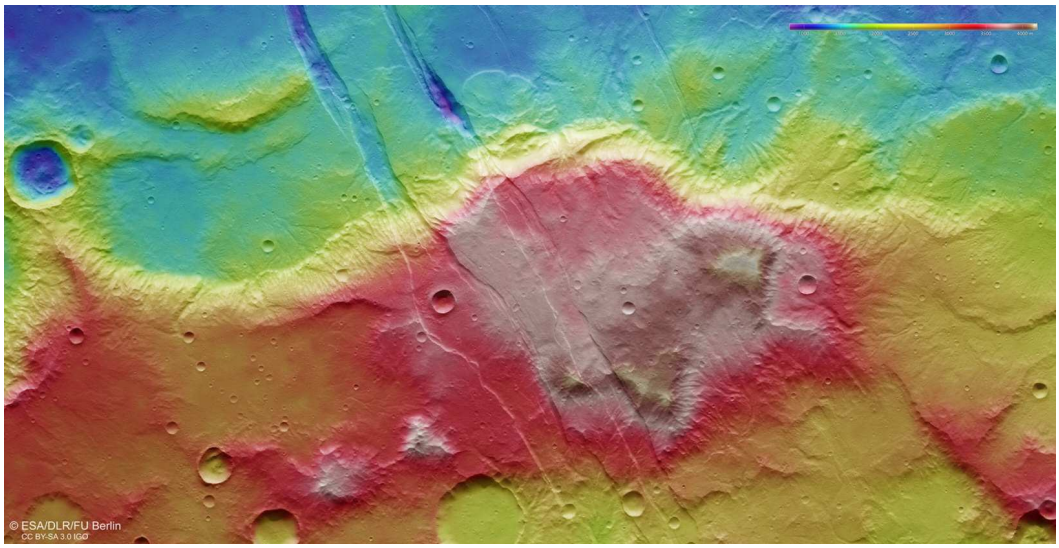
the magma chamber emptied. It is also possible that each graben was associated with an ancient volcanic dike: a steep corridor within the rock along which magma from the interior of Mars once propagated upwards, causing cracking along the surface. In this case the graben could represent a giant 'dike swarm' extending from the volcanic centre. Dike swarms are also seen on Earth, as in Iceland where they are observed with surface fractures and graben sets in the Krafla fissure swarm. As with any geological feature that cuts into the surface of the planet, the graben systems make for a good window into the subsurface.



Colour view of the Sirenum Fossae fracture system on Mars, located about 1800 km southwest of the vast Tharsis volcanic region. The images were acquired by the High Resolution Stereo Camera on Mars Express 5 March 2017. The ground resolution is approximately 14 m/pixel and the images are centered at 28°S / 215°E. [ESA/DLR/FU Berlin, CC BY-SA 3.0 IGO]

They also provide steep surfaces for active processes occurring in more recent times. For example, NASA's Mars Reconnaissance Orbiter identified gullies on some of the steep slopes in Sirenum Fossae, along troughs and in the rims of impact craters.

What material carves out the small channels is a topic of active research: they were initially thought to be related to flowing water, but recent proposals suggest that seasonal frozen carbon dioxide – dry ice – flowing downslope may be responsible. ■



This image shows the relative heights and depths of a region in the southern hemisphere of Mars showing the Sirenum Fossae fracture system. As indicated in the key at top right, whites and browns/reds represent the highest terrain, while blue/purple is the lowest (values are marked on the scale). [ESA/DLR/FU Berlin, CC BY-SA 3.0 IGO]

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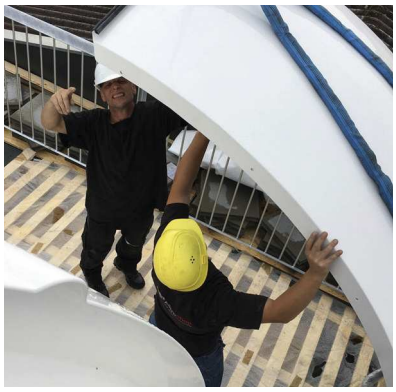

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Hubble observes exoplanet that snows sunscreen

by NASA

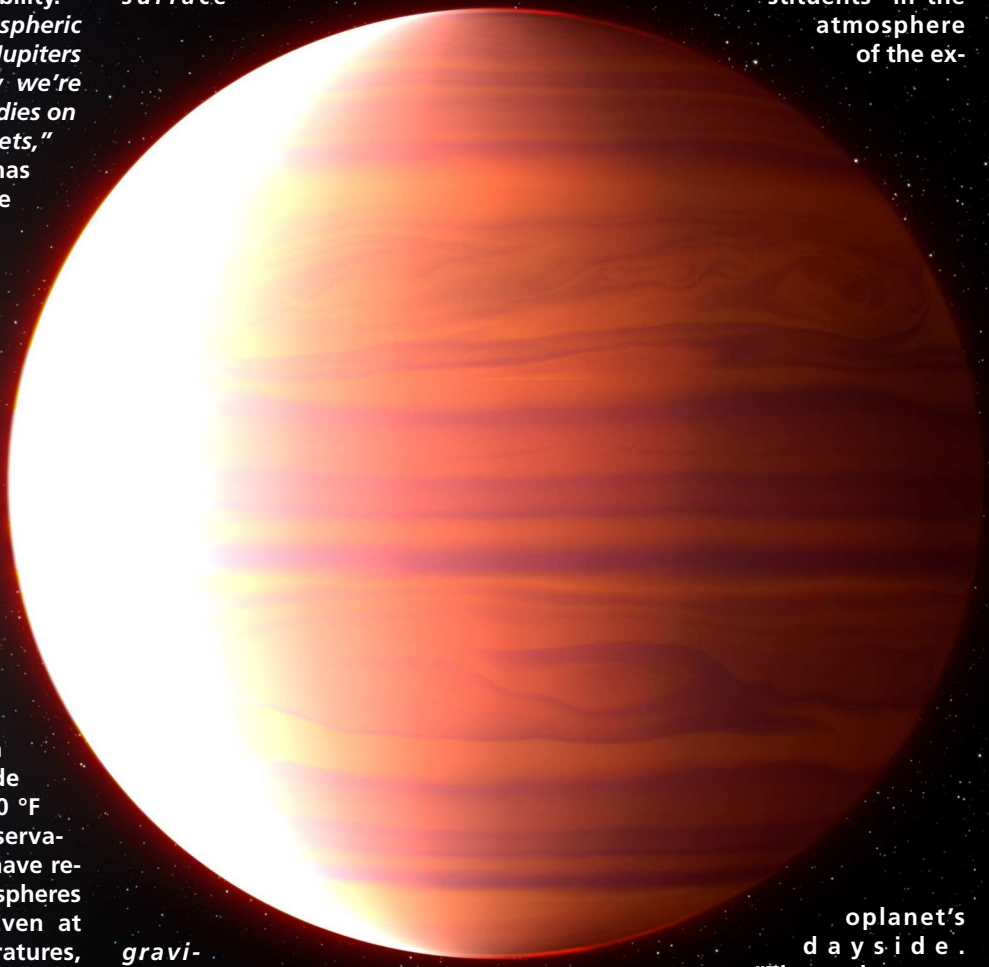
NASA's Hubble Space Telescope has found a blistering hot planet outside our solar system where it "snows" sunscreen. The problem is the sunscreen (titanium dioxide) precipitation only happens on the planet's permanent nighttime side. Any possible visitors to the exoplanet, called Kepler-13Ab, would need to bottle up some of that sunscreen, because they won't find it on the sizzling hot, daytime side, which always faces its host star. Hubble astronomers suggest that powerful winds carry the titanium oxide gas around to the colder nighttime side, where it condenses into crystalline flakes called titanium dioxide, forms clouds, and precipitates as snow. Kepler-13Ab's strong surface gravity — six times greater than Jupiter's — pulls the titanium dioxide snow out of the upper atmosphere and traps it in the lower atmosphere.

Astronomers using Hubble didn't look for titanium oxide specifically. Instead, they observed that the giant planet's atmosphere is cooler at higher altitudes, which is contrary to what was expected. This finding led the researchers to conclude that a light-absorbing gaseous form of titanium oxide, commonly found in this class of star-hugging, gas giant planet known as a "hot Jupiter," has been removed from the dayside's atmosphere. The Hubble observations represent the first time astronomers have detected this precipitation process, called a "cold trap," on an exoplanet. Without the titanium oxide gas to absorb incoming starlight on the daytime side, the atmospheric temperature grows colder with increasing altitude. Normally, titanium oxide in the atmospheres of hot Jupiters absorbs light and reradiates it as heat, making the atmosphere grow warmer at higher altitudes.

This illustration shows the seething hot planet Kepler-13Ab that circles very close to its host star, Kepler-13A. Seen in the background is the star's binary companion, Kepler-13B, and the third member of the multiple-star system is the orange dwarf star Kepler-13C. [NASA, ESA, and G. Bacon (STScI)]

These kinds of observations provide insight into the complexity of weather and atmospheric composition on exoplanets, and may someday be applicable to analyzing Earth-size planets for habitability. *"In many ways, the atmospheric studies we're doing on hot Jupiters now are testbeds for how we're going to do atmospheric studies on terrestrial, Earth-like planets,"* said lead researcher Thomas Beatty of Pennsylvania State University in University Park. *"Hot Jupiters provide us with the best views of what climates on other worlds are like. Understanding the atmospheres on these planets and how they work, which is not understood in detail, will help us when we study these smaller planets that are harder to see and have more complicated features in their atmospheres."*

Beatty's team selected Kepler-13Ab because it is one of the hottest of the known exoplanets, with a dayside temperature of nearly 5,000 °F (near-ly 2,800 °C). Past observations of other hot Jupiters have revealed that the upper atmospheres increase in temperature. Even at their much colder temperatures, most of our solar system's gas giants also exhibit this phenomenon. Kepler-13Ab is so close to its parent star that it is tidally locked. One side of the planet always faces the star; the other side is in permanent darkness. (Similarly, our Moon is tidally locked to Earth; only one hemisphere is permanently visible from Earth.) The observations confirm a theory from several years ago that this kind of precipitation could occur on massive, hot planets with powerful gravity. *"Presumably, this precipitation process is happening on most of the observed hot Jupiters, but those gas giants all have lower surface gravities than Kepler-13Ab,"* Beatty explained. *"The titanium oxide snow doesn't fall far enough in those atmospheres, and then it gets swept back to the hotter dayside, revaporizes, and returns to a gaseous state."* The researchers used Hubble's Wide Field Camera 3 to conduct spectroscopic observations of the exoplanet's atmosphere in near-infrared light.



Hubble made the observations as the distant world traveled behind its star, an event called a secondary eclipse. This type of eclipse yields information on the temperature of the constituents in the atmosphere of the exoplanet's dayside. *"These observations of Kepler-13Ab are telling us how condensates and clouds form in the atmospheres of very hot Jupiters, and how gravity will affect the composition of an atmosphere,"* Beatty explained. *"When looking at these planets, you need to know not only how hot they are but what their gravity is like."*

The Kepler-13 system resides 1,730 light-years from Earth. ■

First light for ESPRESSO

by ESO

ESPRESSO has achieved first light on ESO's Very Large Telescope at the Paranal Observatory in northern Chile. ESPRESSO was designed and built by a consortium consisting of: the Astronomical Observatory of the University of Geneva and University of Bern, Switzerland; INAF–Osservatorio Astronomico di Trieste and INAF–Osservatorio Astronomico di Brera, Italy; Instituto de Astrofísica de Canarias, Spain; Instituto de Astrofisica e Ciências do Espaço, Universidade do Porto and Universidade de Lisboa, Portugal; and ESO. The co-principal investigators are Francesco Pepe (University of Geneva, Switzerland), Stefano Cristiani (INAF–Osservatorio Astronomico di Trieste, Italy), Rafael Rebolo (IAC, Tenerife, Spain) and Nuno Santos (Instituto de Astrofisica e Ciencias do Espaco, Universidade do Porto, Portugal).

This new, third-generation echelle spectrograph is the successor to ESO's hugely successful HARPS instrument at the La Silla Observatory.

The Echelle SPectrograph for Rocky Exoplanet and Stable Spectroscopic Observations (ESPRESSO) successfully made its first observations in November 2017. Installed on ESO's Very Large Telescope (VLT) in Chile, ESPRESSO will search for exoplanets with unprecedented precision by looking at the minuscule changes in the properties of light coming from their host stars. For the first time ever, an instrument will be able to sum up the light from all four VLT telescopes and achieve the light collecting power of a 16-metre telescope. This picture shows a group picture of the happy first light team on the platform at Paranal, with the VLT in the background. [Giorgio Calderone, INAF Trieste]

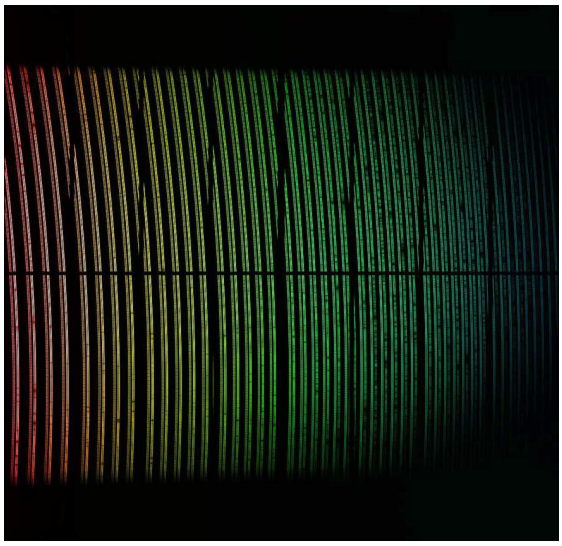
HARPS can attain a precision of around one metre per second in velocity measurements, whereas ESPRESSO aims to achieve a precision of just a few centimetres per second, due to advances in technology and its placement on a much bigger telescope.

The lead scientist for ESPRESSO, Francesco Pepe from the University of Geneva in Switzerland, explains its significance: *"This success is the result of the work of many people over 10 years. ESPRESSO isn't just the evolution of our previous instruments like HARPS, but it will be transformational, with its higher resolution and higher precision. And unlike earlier instruments it can exploit the VLT's full collecting power — it can be used with all four of the VLT Unit Telescopes at the same time to simulate a 16-metre telescope. ESPRESSO will be unsurpassed for at least a decade — now I am just impatient to find our first rocky planet!"* ESPRESSO can detect tiny changes in the spectra of stars as a planet orbits. This radial velocity method works because a planet's gravitational pull influences its host star, causing it to "wobble" slightly. The less massive the planet, the smaller the wobble, and so for rocky and possibly life-bearing exoplanets to be detected, an instrument with very high precision is required. With this method, ESPRESSO will be able to detect some of the lightest planets ever found.

The test observations included observations of stars and known planetary systems. Comparisons with existing HARPS data showed that ESPRESSO can obtain similar quality data with dramatically less exposure time. Instrument scientist Gaspare Lo Curto (ESO) is delighted: *"Bringing ESPRESSO this far has been a great accomplishment, with contributions from an international consortium as well as many different groups within ESO: engineers, astronomers and administration. They had to not just install the spectrograph itself, but also the very complex optics that bring the light together from the four VLT Unit Telescopes."*

Although the main goal of ESPRESSO is to push planet hunting to the next level, finding and characterising less massive planets and their atmospheres, it also has many other applications. ESPRESSO will also be the world's most powerful tool to test whether the physical constants of nature have changed since the Universe was young.

Such tiny changes are predicted by some theories of fundamental physics, but have never been convincingly observed. When ESO's Extremely Large Telescope comes on line, the instrument HIRES, which is currently under conceptual design, will enable the detection and characterisation of even smaller and lighter exoplanets, down to Earth-like planets, as well as the study of exoplanet atmospheres with the prospect of the detection of signatures of life on rocky planets. ■



This colourful image shows spectral data from the First Light of the ESPRESSO instrument on ESO's Very Large Telescope in Chile. The light from a star has been dispersed into its component colours. This view has been colourised to indicate how the wavelengths change across the image, but these are not exactly the colours that would be seen visually. Close inspection shows many dark spectral lines in the stellar spectra and also the regular double spots from a calibration light source. The dark gaps are features of how the data is taken, and are not real. [ESO/ESPRESSO team]

ESPRESSO successfully made its first observations in November 2017. Installed on ESO's Very Large Telescope (VLT) in Chile, ESPRESSO will search for exoplanets with unprecedented precision by looking at the minuscule changes in the properties of light coming from their host stars. For the first time ever, an instrument will be able to sum up the light from all four VLT telescopes and achieve the light collecting power of a 16-metre telescope. [ESO/P. Horálek]

Chicxulub: perfect timing... for us!

by Michele Ferrara

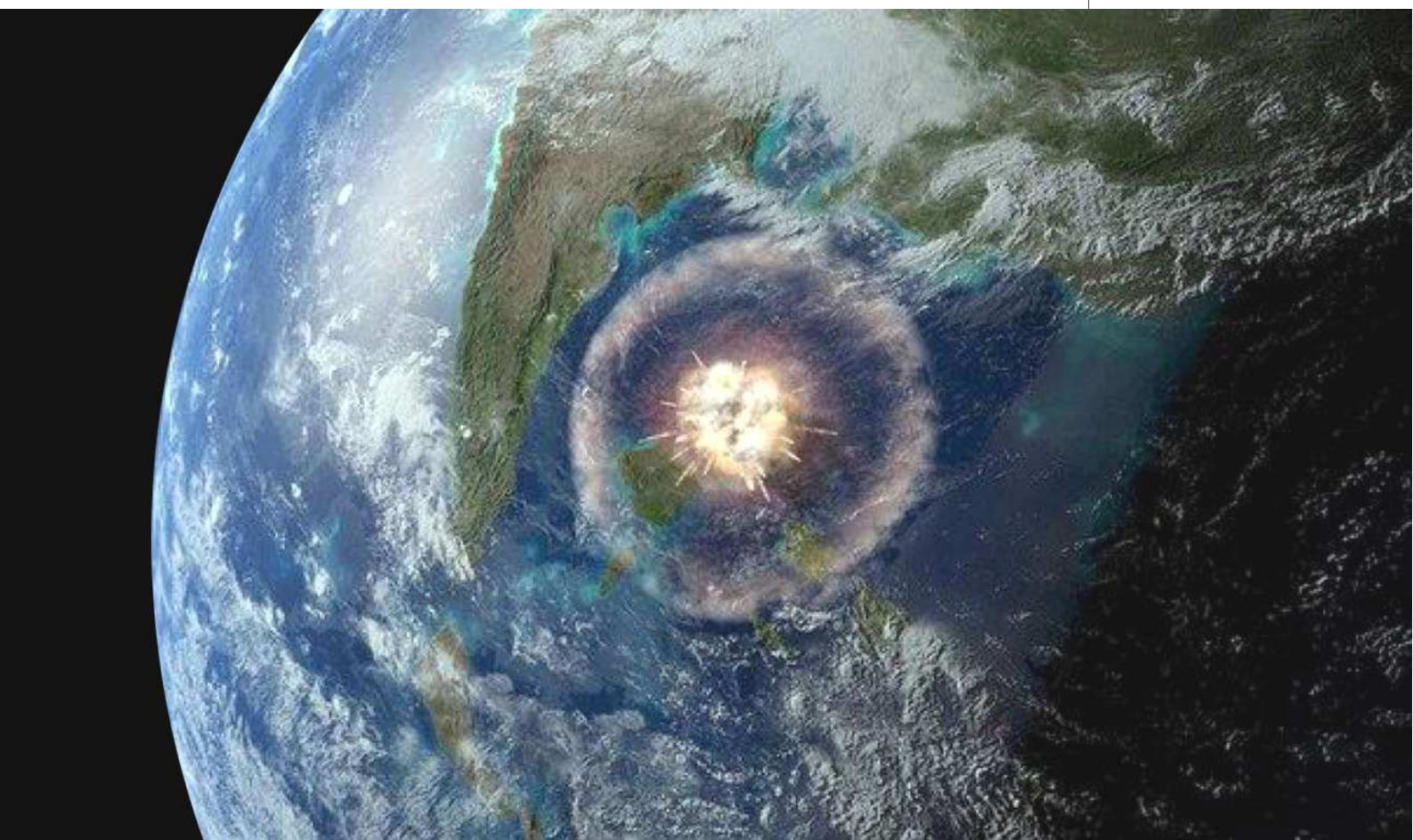
Two Japanese researchers have concluded that the evolution of mammals from the Cretaceous to today would have been entirely different if the asteroid which put an end to that period, 79 million years long and dominated by dinosaurs, had fallen on areas with different petrological properties. The mass extinction caused by that event had only a thirteen percent probability of occurring and leading to the appearance of humankind.

The fires triggered by the return to Earth of the blazing material thrown into the atmosphere by the impact of Chicxulub have until now been considered the critical element in the mass extinction at the end of the Cretaceous. The reality could be different.

One of the most relevant events in the history of life on our planet is the impact of the asteroid that produced a mass extinction 66 million years ago, sweeping away about 75% of the living species and putting an end to the domination of the great reptiles. The asteroid, 9-12 km in diameter, fell into the current Gulf of Mexico, off the Yucatan peninsula, blasting out a crater more than 180 km in diameter. This crater remained hidden underground until the '70s, before being randomly discovered by two geophysicists searching for oil fields. As the epicentre of the impact was relatively close to the current town of Chicxulub, the researchers agreed to call the crater, the asteroid and the event by the same name: Chicxulub.

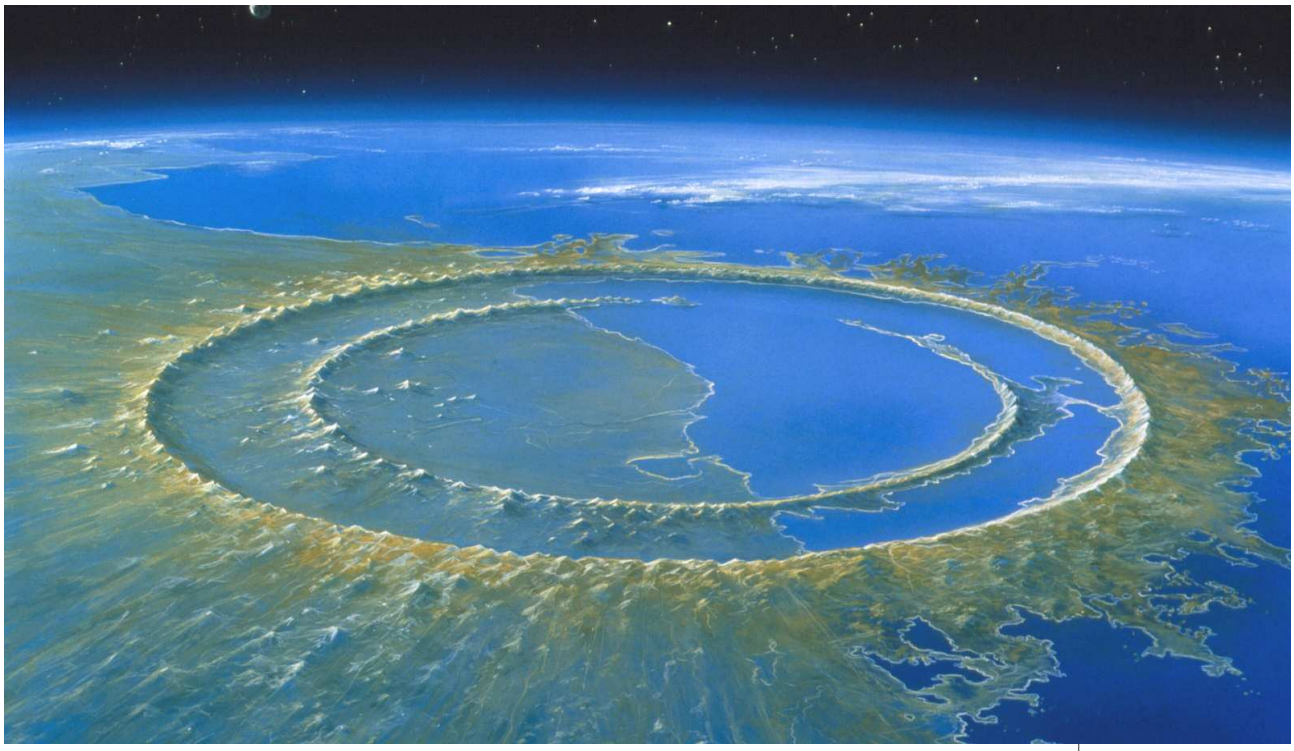
In addition to the immediate, apocalyptic aftermath of the impact on a regional and continental scale, the event also had catastrophic effects on a planetary scale due to trillions of tons of material of varying consistencies and sizes thrown into the troposphere, the stratosphere and beyond. According to the prevailing theory, when the heaviest part of that material plunged to the ground in the form of burning meteorites, it triggered an extensive series of fires in forests around the globe, producing huge amounts of soot dispersed by atmospheric circulation and then returning to the ground in rainfall. Once the soot reached the ground, it settled in a geological layer that tells us the time of the impact (66,038,000 ±11,000 years ago) along with other materials, including significant quantities of iridium from the asteroid. During its stay in the atmosphere, the soot prevented part of the solar radiation from reaching the surface, and this triggered a drop in the global average temperature, directly causing the mass extinction at a point between the Cretaceous and Paleogene eras (K-Pg boundary).

Visualization of the asteroid impact that 66 million years ago killed 75% of living species on Earth. [R. Michalik, D. Dolak, The Science Insitute Columbia College, Chicago] Below, a representation of the Chicxulub impoact seen from space. [Joe Tucciarone, Science Source]



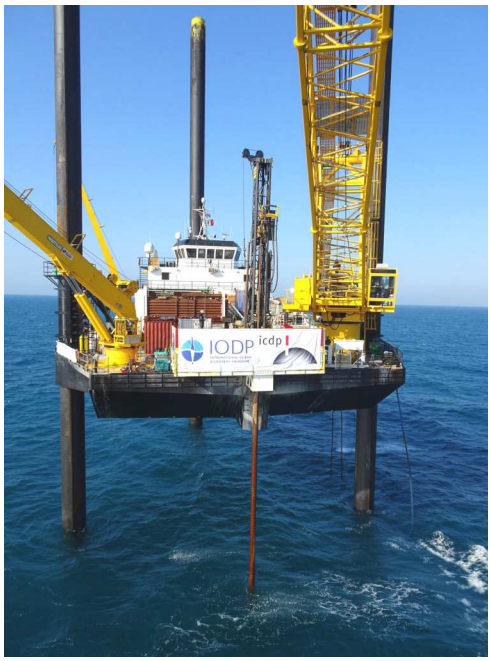
Dramatic scenes of the end of dinosaurs, following the event of Chicxulub. In the view above, a few days have passed since the impact. In the one below, a few years have passed, and the mass extinction is complete.

This general picture of the Chicxulub event and its consequences is broadly shared by an overwhelming majority of scientists, although some specific aspects could be interpreted differently. This is the case with a study by Kunio Kaiho (Tohoku University, Sendai) and Naga Oshima (Meteorological Research Institute, Tsukuba) recently published in *Scientific Reports*. The two researchers claim that the widespread fires in vegetation triggered by the burning material falling back to the ground cannot have generated enough soot to create a significant global drop in temperature. Moreover, the fires certainly affected every continent, so the distribution of soot in the atmosphere had to be fairly uniform, while there is evidence that indicates a more severe cooling in the northern hemisphere and a faster return to normal in the southern one. Above all, forest fires would have emitted soot only into the troposphere, where its stay would have been slightly limited — perhaps weeks — before it was totally removed by rainfall. Such a short period of darkness would not have



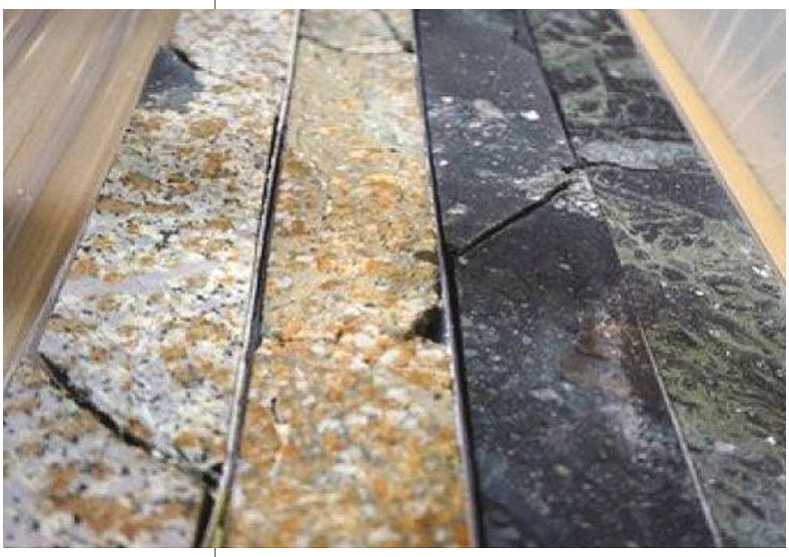
significantly reduced temperatures long enough to cause a mass extinction. The soot must, therefore, have been in the stratosphere (where it could have persisted for years), and only the soot produced and ejected as a direct result of the impact could have gotten so high.

By studying this aspect of the Chicxulub event through a series of computer simulations, Kaiho and Oshima discovered that the asteroid, to transfer the necessary quantity of elements in suspension into the stratosphere, must have hit sedimentary rocks particularly rich in hydrocarbons and sulfates. By burning at the very high temperature produced by the impact, these elements turned into soot and aerosols. The most surprising aspect is that only about 13% of the Earth's surface contains rocks with that composition, and only by striking those areas could the asteroid have produced a mass extinction. In other words, if the asteroid had fallen anywhere in the remaining 87% of the Earth's surface, the effects on the biosphere would have been devastating over a region or, at most, a continent, and the dinosaurs would not have died out. In this case, the evolution of life on Earth would



Artist's reconstruction of Chicxulub crater soon after impact, 66 million years ago. [Detlev Van Ravenswaay/Science Source] On the side, Liftboat Myrtle is a drilling platform normally used for oil operations. Since April 2016, geologists have been using it in the Gulf of Mexico to drill into the crater Chicxulub. [ELeBer/ ECORD/ IODP]

Several samples of material taken from the Chicxulub crater using the Liftboat Myrtle platform's auger. They are essentially a mixture of terrestrial rock and residual material from the asteroid.



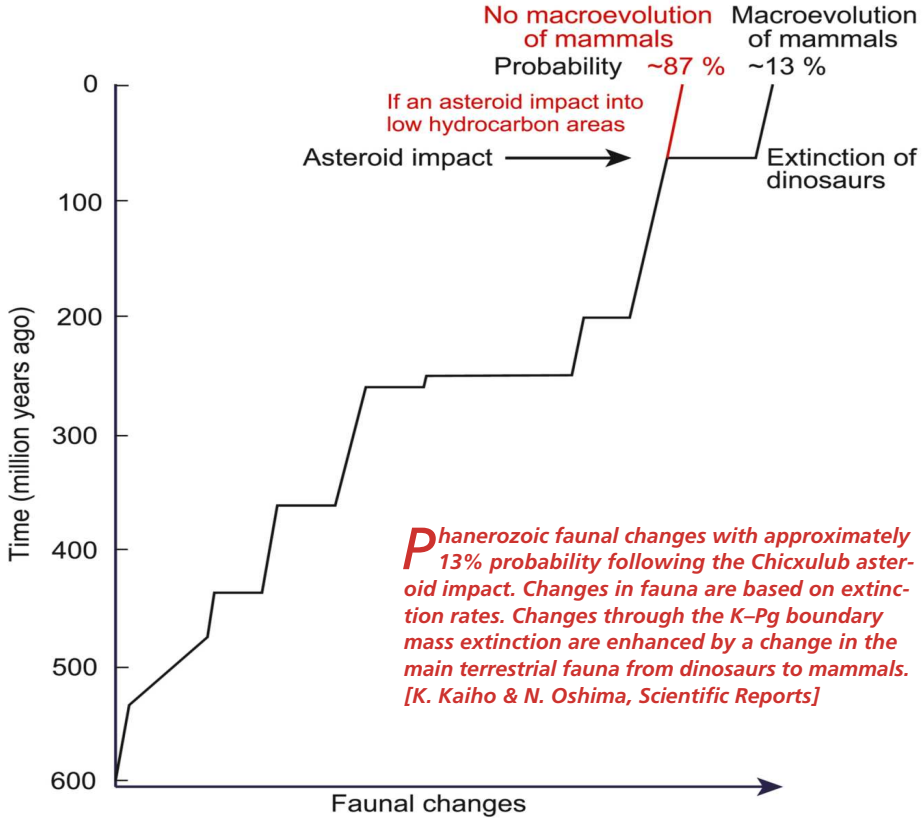
very probably have taken a deeply different path from the one that led to the appearance of the human being.

Kaiho and Oshima comment in more detail below on the results of their simulations in *Scientific Reports*. Please note that the two researchers indicate soot with the abbreviation BC, from black carbon, and indicate the quantities in teragrams, Tg (1 Tg = 1 million tons).

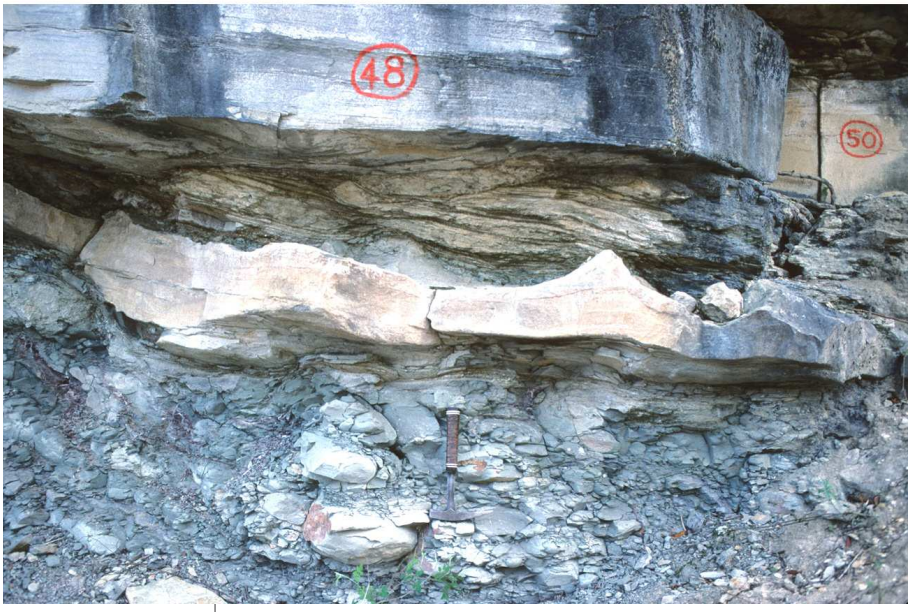
"We estimated climate changes caused by BC injection due to the Chicxulub asteroid impact for five quantities of BC (20, 200, 500, 1500, and 2600-Tg BC ejection cases) using global climate model calculations. Although BC in the troposphere was efficiently removed from the atmosphere by precipitation (within approximately 1 week), BC in the stratosphere had a longer lifetime and was gradually deposited on the surface, on a scale of several years. The stratospheric BC rapidly reduced the sunlight reaching the Earth's surface, which led to a cooling of the tropospheric atmosphere and ocean, and a decrease in precipitation on a global scale. These climate

A piece of the asteroid that made the Chicxulub Crater. [Photograph by Faith Tucker, NASA]

changes were greater for larger BC ejections. Changes in the atmosphere showed a rapid response immediately after the impact: up to 0–0.5 °C, 2–3 °C, 4–6 °C, 8–10 °C, and 8–11 °C cooling of the global mean surface air temperature, 0–1 °C, 4–5 °C, 6–9 °C, 10–16 °C, and 10–18 °C cooling of the global mean surface air temperature on land, and 0–15%, 25–50%, 45–70%, 65–80%, and 75–85% decreases in global mean precipitation on land for 20-, 200-, 500-, 1500-, and 2600-Tg BC ejection cases, respectively, within a few years after the impact. Temperature and precipitation gradually recovered within the following 10 years. Seawater temperature changes exhibited a slower response following the impact, and cooling at shallower water



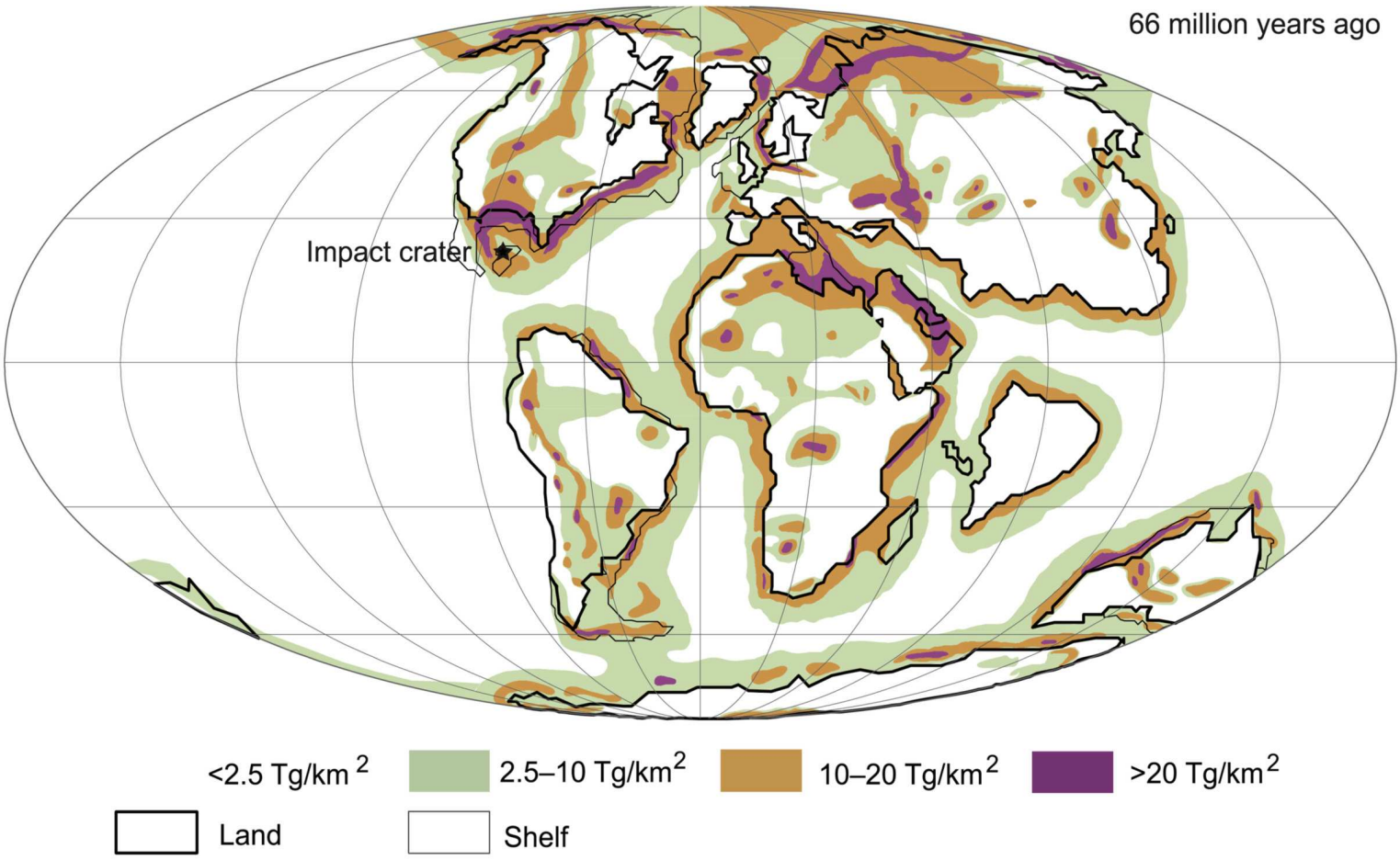
Phanerozoic faunal changes with approximately 13% probability following the Chicxulub asteroid impact. Changes in fauna are based on extinction rates. Changes through the K–Pg boundary mass extinction are enhanced by a change in the main terrestrial fauna from dinosaurs to mammals. [K. Kaiho & N. Oshima, Scientific Reports]



An outcrop of rock in Arroyo el Mimbral, Tamaulipas, Mexico, is a good example of the complex deposits of impact debris and other sediment produced by the Chicxulub impact event. The lower portion of the sequence (bottom panel) is composed of altered impact melt spherules with an interbedded sandy limestone, and overlain with a laminated sandstone. The base of the laminated sandstone contains plant debris, even though these sediments were deposited on the seafloor beneath ~500 meters of water. The upper portion of the sequence (upper panel) is composed of layers of sandstone, siltstone, and mudstone. The top of the sequence, where the hammer is resting, contains anomalously high concentrations of the element iridium, which was produced from the vaporized impactor that produced the Chicxulub crater. [David A. Kring]

depths (<100 m) was faster and greater than cooling at greater water depths (e.g., up to 0.5 °C, 2 °C, 4 °C, 7 °C, and 9 °C decrease in global mean seawater temperature at a 2-m water depth for 20-, 200-, 500-, 1500-, and 2600-Tg BC ejection cases, respectively, within 1–4 years after the impact, and within 1 °C cooling at a 600-m water depth for all cases within >10 years).”

It is interesting to note that global cooling also led to a significant drop in precipitation, perhaps a drastic one due to high levels of soot emitted into the stratosphere. Less light, more frost and less water can only have been a devastating mixture that damaged vegetation and the terricolous and aquatic organisms at the base of the food chain. It is easy to understand that a few years of that scenario were enough to annihilate many living species, and in particular the dinosaurs, the cold-blooded animals (or lukewarm, as some studies would have it) then at the top of the food chain. As the same researchers pointed out in a previous work, a mass extinction would have required a global drop in the surface air temperature of about 8-10 °C, a value that may only have been reached if the Chicxulub asteroid had hit an area with a high concentration of hydrocarbons and sulfates. This eventuality is confirmed



by the fact that the mostly coastal location of oil fields and other non-renewable energy sources at the end of the Cretaceous period did not differ much from that of today (as shown by maps reconstructed through estimates made by Kaiho). In this context, the Gulf of Mexico was and still is rich in hydrocarbons.

In addition to the burning of hydrocarbons, a primary role in the cooling of the climate was probably played by the sulfates present in the rocks impacted by the asteroid. It is not easy to determine how much sulfates affected the mass extinction, but it has been calculated that by themselves they may have contributed to lowering the global temperature by 14 °C if there were high concentrations in the rocks (1-2% of the terrestrial surface).

Here's how Kaiho and Oshima summarize the scenario in *Scientific Reports*:

"These results suggest that climate changes (in terms of extinction levels) can be estimated using stratospheric soot amounts. Soot from hydrocarbon-rich areas (approximately 13%) including high sulfate areas limited to 1% of the Earth's surface caused 8– ≥ 11 °C global cooling, 13– ≥ 17 °C cooling on land, a decrease in precipitation by approximately 70– ≥ 85% on land, a decrease of approximately 5– ≥ 7 °C in seawater temperature at a 50-m water depth, and mass extinction marked by the extinction of dinosaurs. [...] The Chicxulub impact occurred in a hydrocarbon-rich, sulfate-dominated area, and is a rare case of mass extinction being caused at such an impact site. [...] The probability of mass extinction at the K–Pg boundary was approximately 13% after the asteroid impacted Earth. The collapse of ecosystems with dinosaurs on land and large marine reptiles and ammonites in the sea at the top of the food chain was probably due to soot with possible contributions by sulfate from the Chicxulub asteroid impact and led to the subsequent macroevolution and diversification of mammals. Therefore, the low probability of mass extinction indicates the low probability of the subsequent macroevolution of mammals."

The conclusions reached by the two Japanese researchers through their computer simulations make us reflect on how unlucky the dominant species was at the end of the Cretaceous period and, from a different perspective, what a great stroke of luck the Chicxulub event was for the mammals. How would life on Earth have evolved if that asteroid was a little further ahead or a bit further back in its orbit and had slammed into our planet a few hundred kilometres away from where it fell? ■

Global map showing the amount of organic matter in sedimentary rocks ejected if the Chicxulub asteroid hit various locations at the end of the Cretaceous. Shaded areas correspond to 0–4 °C, 4–8 °C, 8–11 °C, and ≥11 °C cooling. Mass extinction could have been caused by 8–11 °C or more cooling when the asteroid hit an orange or magenta area, which occupied approximately 13% of the Earth's surface. The map is based on Courtillot et al.; thin lines indicate continental crust shelf edges. [K. Kaiho & N. Oshima, Scientific Reports]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ALMA discovers cold dust around nearest star

by ESO

Proxima Centauri is the closest star to the Sun. It is a faint red dwarf lying just four light-years away in the southern constellation of Centaurus (The Centaur). It is orbited by the Earth-sized temperate world Proxima b, discovered in 2016 and the closest planet to the Solar System. But there is more to this system than just a single planet. The new ALMA observations reveal emission from clouds of cold cosmic dust surrounding the star.

The lead author of the new study, Guillem Anglada, from the Instituto de Astrofísica de Andalucía (CSIC), Granada, Spain, explains the significance of this find: *"The dust around Proxima is important because, following the discovery of the terrestrial planet Proxima b, it's the first indication of the presence of an elaborate planetary system, and not just a single planet, around the star closest to our Sun."*

Dust belts are the remains of material that did not form into larger bodies such as planets. The particles of rock and ice in these belts vary in size from the tiniest dust grain, smaller than a millimetre across, up to asteroid-like bodies many kilometres in diameter. Dust appears to lie in a belt that extends a few hundred million kilometres from Proxima Centauri and has a total mass of about one hundredth of the Earth's mass. This belt is estimated to have a temperature of about –230 degrees Celsius, as cold as that of the Kuiper Belt in the outer Solar System. There are also hints in the ALMA data of another belt of even colder dust about ten times further out. If confirmed, the nature of an outer belt is intriguing, given its very cold environment far from a star that is cooler and fainter than

This artist's impression shows how the newly discovered belts of dust around the closest star to the Solar System, Proxima Centauri, may look. ALMA observations revealed the glow coming from cold dust in a region between one to four times as far from Proxima Centauri as the Earth is from the Sun. The data also hint at the presence of an even cooler outer dust belt and indicate the presence of an elaborate planetary system. These structures are similar to the much larger belts in the Solar System and are also expected to be made from particles of rock and ice that failed to form planets. Note that this sketch is not to scale — to make Proxima b clearly visible it has been shown further from the star and larger than it is in reality. [ESO/M. Kornmesser]

the Sun. Both belts are much further from Proxima Centauri than the planet Proxima b, which orbits at just four million kilometres from its parent star. Guillem Anglada explains the implications of the discovery: *"This result suggests that Proxima Centauri may have a multiple planet system with a rich history of interactions that resulted in the formation of a dust belt. Further study may also provide information that might point to the locations of as yet unidentified additional planets."*

Proxima Centauri's planetary system is also particularly interesting because there are plans — the Starshot project — for future direct exploration of the system with microprobes attached to laser-driven sails. A knowledge of the dust environment around the star is essential for planning such a mission.

Co-author Pedro Amado, also from the Instituto de Astrofísica de Andalucía, explains that this observation is just the start: *"These first results show that ALMA can detect dust structures orbiting around Proxima. Further observations will give us a more detailed picture of Proxima's planetary system. In combination with the study of protoplanetary discs around young stars, many of the details of the processes that led to the formation of the Earth and the Solar System about 4600 million years ago will be unveiled. What we are seeing now is just the appetiser compared to what is coming!"*

This artist's video impression shows how the newly discovered belts of dust around the closest star to the Solar System, Proxima Centauri, may look. [ESO/M. Kornmesser]

ESA: crossing drones with satellite

by ESA

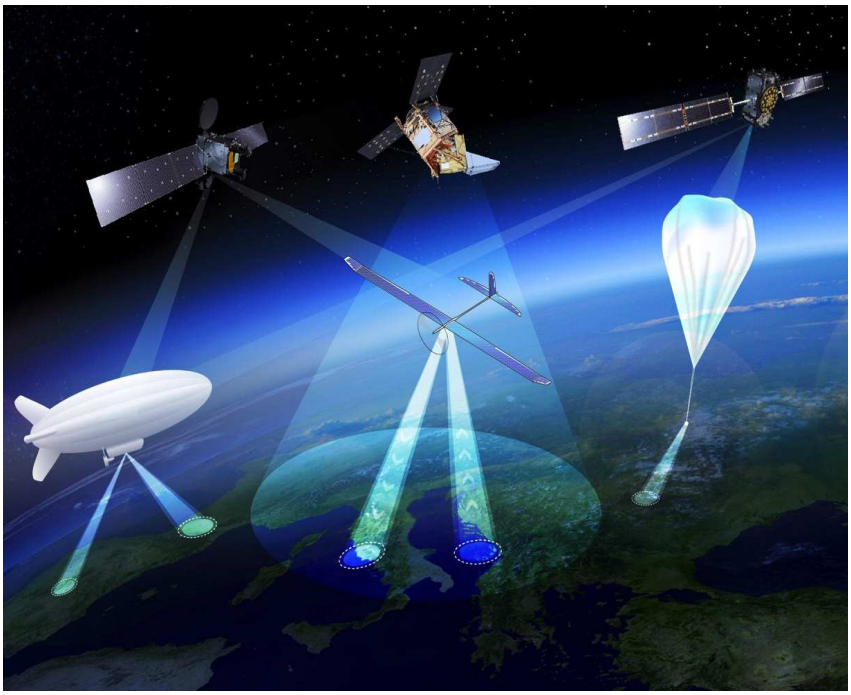
ESA is considering extending its activities to a new region of the sky via a novel type of aerial vehicle, a 'missing link' between drones and satellites. High Altitude Pseudo-Satellites, or HAPS, are platforms that float or fly at high altitude like conventional aircraft but operate more like satellites – except that rather than working from space they can remain in position inside the atmosphere for weeks or even months, offering continuous coverage of the territory below.

The best working altitude is about 20 km, above the clouds and jet streams, and 10 km above commercial airliners, where wind speeds are low enough for them to hold position for long periods.

From such a height they can survey the ground to the horizon 500 km away, variously enabling precise monitoring and surveillance, high-bandwidth communications or back up to existing satellite navigation services.

Several ESA directorates have teamed up to investigate their potential, explains future-systems specialist Antonio Ciccolella: *"For Earth observation, they could provide prolonged high-resolution coverage for priority regions, while for navigation and telecoms they could shrink blind spots in coverage and combine wide bandwidth with negligible signal delay. ESA is looking into how these various domains can be best brought together."* Earth observation specialist Thorsten Fehr explains: *"We've been looking into the concept for the last 20 years but now finally it's becoming reality. That's come about through the maturing of key technologies: miniaturised avionics, high-performance solar cells, lightweight batteries and harness, miniaturisation of Earth observation sensors and high-bandwidth communication links that can deliver competitively priced services."*

Navigation engineer Roberto Prieto Cerdeira adds: *"There's obvious potential for emergency response.*



High Altitude Pseudo-Satellites, or HAPS, are platforms that float or fly at high altitude like conventional aircraft but operate more like satellites – except that rather than working from space they can remain in position inside the atmosphere for weeks or even months, variously enabling precise monitoring and surveillance, high-bandwidth communications or back up to existing satellite navigation services. [ESA Earth Observation Graphics Bureau]

The QinetiQ-designed and Airbus-owned Zephyr-7 solar-powered unmanned aircraft holds the world flight endurance record, having remained aloft from 9 July to 23 July 2010 for a total of 336 hours, 22 minutes and 8 seconds – upwards of 14 days. The design is part of the Airbus High Altitude Pseudo-Satellite programme, with a larger double-tailed Zephyr-T variant under construction. [Airbus]

They could also be employed semi-permanently, perhaps extending satnav coverage into high, narrow valleys and cities."

Thales Alenia Space's Stratobus airship can carry up to 250 kg of payload; its electric engines flying against the breeze to hold itself in position, and relying on fuel cells at night. Its first flight is projected for 2021. [Thales Alenia Space/Briot]

European companies have already unveiled product lines. For instance, Airbus has developed the winged, solar-powered Zephyr, which in 2010 achieved a world record 14 days of continuous flight without refuelling.

Zephyr-S is designed to fly payloads of a few tens of kilograms for up to three months at a time, with secondary batteries employed to keep it powered and aloft overnight. A larger Zephyr-T version in preparation will support larger payloads and power needs.

Thales Alenia Space is meanwhile preparing the lighter-than-air Stratobus, with its first flight expected in 2021.

The buoyant Stratobus airship can carry up to 250 kg; its electric engines flying against the breeze to hold itself in position, relying on fuel cells at night. ■

Closest temperate world orbiting quiet star discovered

by ESO

A team working with ESO's High Accuracy Radial velocity Planet Searcher (HARPS) at the La Silla Observatory in Chile has found that the red dwarf star Ross 128 is orbited by a low-mass exoplanet every 9.9 days. This Earth-sized world is expected to be temperate, with a surface temperature that may also be close to that of the Earth. Ross 128 is the "quietest" nearby star to host such a temperate exoplanet. *"This discovery is based on more than a decade of HARPS intensive monitoring together with state-of-the-art data reduction and analysis techniques. Only HARPS has demonstrated such a precision and*

This artist's impression shows the temperate planet Ross 128 b, with its red dwarf parent star in the background. This planet, which lies only 11 light-years from Earth, was found by a team using ESO's unique planet-hunting HARPS instrument. The new world is now the second-closest temperate planet to be detected after Proxima b. It is also the closest planet to be discovered orbiting an inactive red dwarf star, which may increase the likelihood that this planet could potentially sustain life. Ross 128 b will be a prime target for ESO's Extremely Large Telescope, which will be able to search for biomarkers in the planet's atmosphere. [ESO/M. Kornmesser]

it remains the best planet hunter of its kind, 15 years after it began operations," explains Nicola Astudillo-Defru (Geneva Observatory – University of Geneva, Switzerland), who co-authored the discovery paper.

Red dwarfs are some of the coolest, faintest — and most common — stars in the Universe. This makes them very good targets in the search for exoplanets and so they are increasingly being studied. In fact, lead author Xavier Bonfils (Institut de Planétologie et d'Astrophysique de Grenoble – Université Grenoble-Alpes/CNRS, Grenoble, France), named their HARPS programme The shortcut to happiness, as it is easier to detect small cool siblings of Earth around these stars, than around stars more similar to the Sun.

Many red dwarf stars, including Proxima Centauri, are subject to flares that occasionally bathe their orbiting planets in deadly ultraviolet and X-ray radiation. However, it seems that Ross 128 is a much quieter star, and so its planets may be the closest known comfortable abode for possible life.

Although it is currently 11 light-years from Earth, Ross 128 is moving towards us and is expected to become our nearest stellar neighbour in just 79,000 years — a blink of the eye in cosmic terms. Ross 128 b will by then take the crown from Proxima b and become the closest exoplanet to Earth! With the data from HARPS, the team found that Ross 128 b orbits 20 times closer than the Earth orbits the Sun. Despite this proximity, Ross 128 b receives only 1.38 times more irradiation than the Earth. As a result, Ross 128 b's equilibrium temperature is estimated to lie between -60 and 20°C, thanks to the cool and faint nature of its small red dwarf host star, which has just over half the surface temperature of the Sun. While the scientists involved in this discovery consider Ross 128b to be a temperate planet, uncertainty remains as to whether the planet lies inside, outside, or on the cusp of the habitable zone, where liquid water may exist on a planet's surface.

Astronomers are now detecting more and more temperate exoplanets, and the next stage will be to study their atmospheres, composition and chemistry in more detail. Vitally, the detection of biomarkers such as oxygen in the very closest exoplanet atmospheres will be a huge next step, which ESO's Extremely Large Telescope (ELT) is in prime position to take.

"New facilities at ESO will first play a critical role in building the census of Earth-mass planets amenable to characterisation.

In particular, NIRPS, the infrared arm of HARPS, will boost our efficiency in observing red dwarfs, which emit most of their radiation in the infrared. And then, the ELT will provide the opportunity to observe and characterise a large fraction of these planets," concludes Xavier Bonfils. ■

NASA's JWST early science observations revealed

by NASA

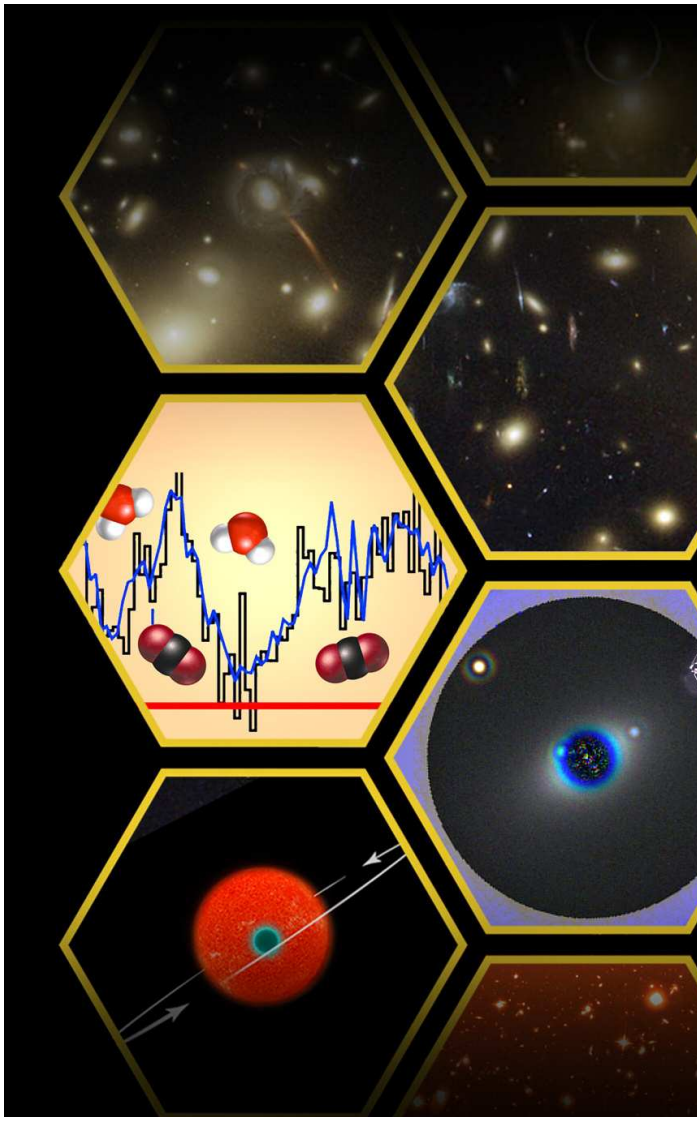
Astronomers around the world will have immediate access to early data from specific science observations from NASA's James Webb Space Telescope, which will be completed within the first five months of Webb's science operations. These observing programs were chosen from a Space Telescope Science Institute call for early release science proposals, and include examining Jupiter and its moons, searching for organic molecules forming around infant stars, weighing supermassive black holes lurking in galactic cores, and hunting for baby galaxies born in the early universe.

"I'm thrilled to see the list of astronomers' most fascinating targets for the Webb telescope, and extremely eager to see the results. We fully expect to be surprised by what we find," said Dr. John C. Mather, Senior Project Scientist for the Webb telescope and Senior Astrophysicist at NASA's Goddard Space Flight Center, Greenbelt, Maryland.

The resulting observations will comprise the Director's Discretionary Early Release Science (DD-ERS), and cover the gamut of Webb science targets, from planets in our solar system to the most distant galaxies. The program provides the entire scientific community with immediate access to Webb data so they have the opportunity to analyze the data and plan follow-up observations.

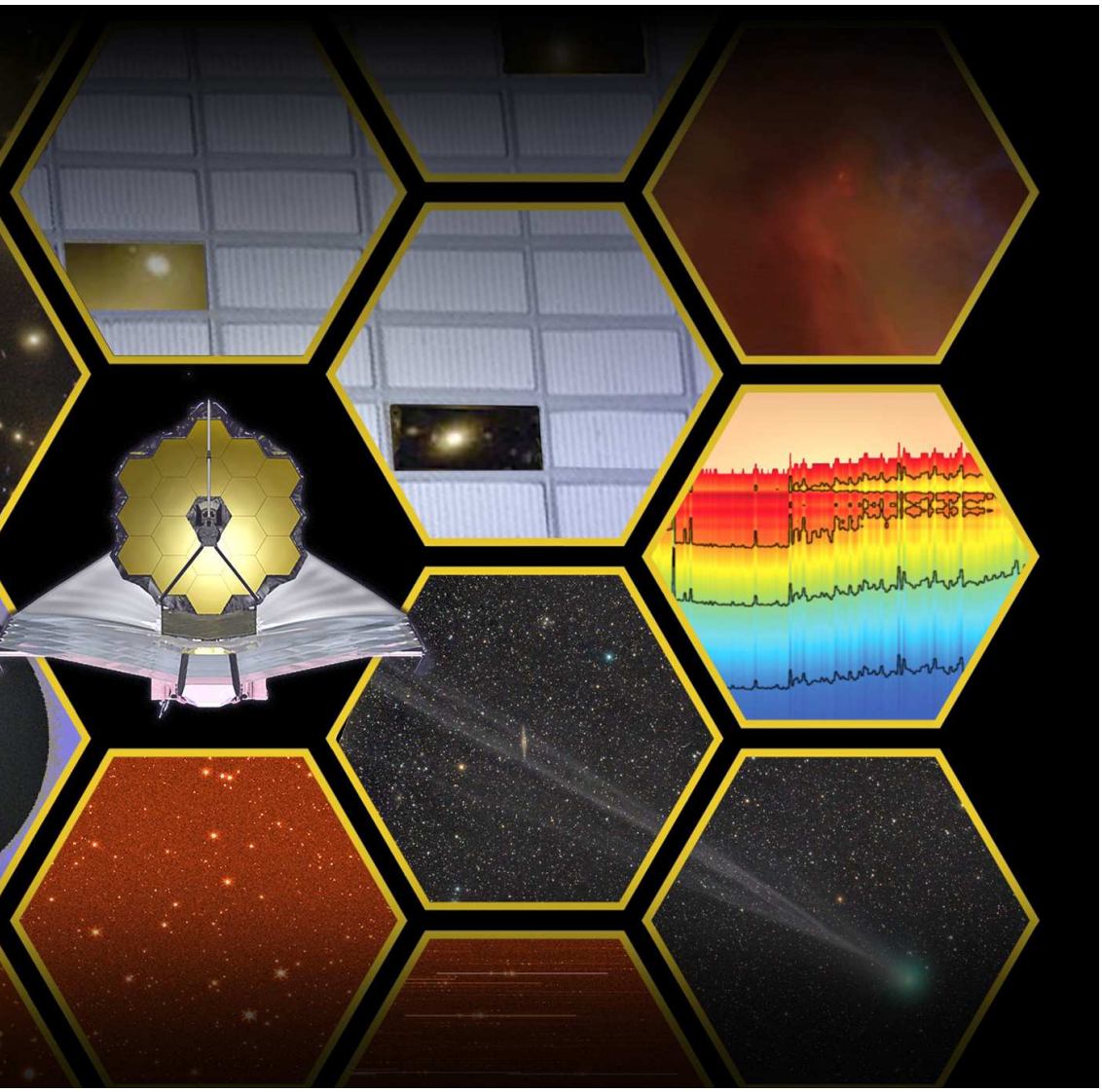
"We were impressed by the high quality of the proposals received," said Dr. Ken Sembach, Director of the Space Telescope Science Institute (STScI) in Baltimore, Maryland. *"These observing programs not only will generate great science, but also will be a unique resource for demonstrating the investigative capabilities of this extraordinary observatory to the worldwide scientific community."*

The observations will also exercise all four of Webb's science instruments, so that the astronomical community can



This artist's illustration represents the scientific capabilities of NASA's James Webb Space Telescope. Both imaging and spectroscopy will be central to the Webb mission. [NASA, ESA, and A. Feild (STScI)]

explore Webb's full potential. Webb has a minimum scientific lifetime of five years, so the scientific community will have to rapidly learn to use its advanced capabilities. *"We want the research community to be as scientifically productive as possible, as early as possible, which is why I am so pleased to be able to dedicate nearly 500 hours of director's discretionary time to these ERS observations,"* said Sembach. One of the most widely anticipated areas of research by Webb is to study planets orbiting other stars. When such an exoplanet passes in front of its host star, starlight filters through the planet's atmosphere, which absorbs certain colors of light depending on the chemical composition. Webb will measure this absorption, using its powerful infrared spectrographs, to look for the chemical fingerprints of the atmosphere's gasses. Astronomers initially will train their gaze onto gaseous Jupiter-sized worlds like WASP-39b and WASP-43b because they are easier targets on which to apply this technique. The results will help guide observing strategies for smaller, mostly rocky and more Earth-like super-Earths, where atmospheric composition may give hints of a planet's potential habitability.



Webb also will peer into the distant universe, examining galaxies whose light has been stretched into infrared wavelengths by the expansion of space.

This infrared region is beyond what Hubble can detect. Galaxy clusters are particularly rich sources of targets, since a cluster's gravity can magnify light from more distant background galaxies. DD-ERS observations will target regions of the sky already examined by Hubble's Frontier Fields program, such as the galaxy cluster MACS J0717.5+3745. Webb data will complement Hubble's, giving astronomers new insights into these cornucopias of galaxies.

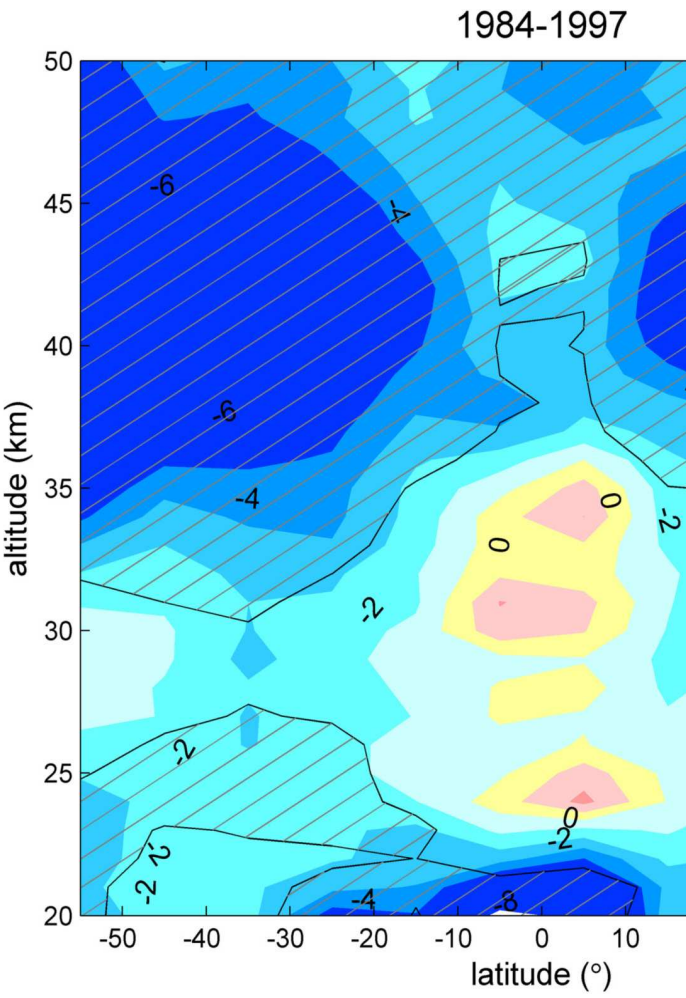
Since Webb must remain shielded from sunlight, its field of view is limited to specific areas of the sky at certain times of year. As a result, the potential targets listed above may shift depending on the launch date.

More than 100 proposals for DD-ERS observations were submitted in August 2017. Of those, 13 programs requesting 460 hours of telescope time were selected following review by panels of subject matter experts and the STScI director. ■

Ozone ups and downs

by ESA

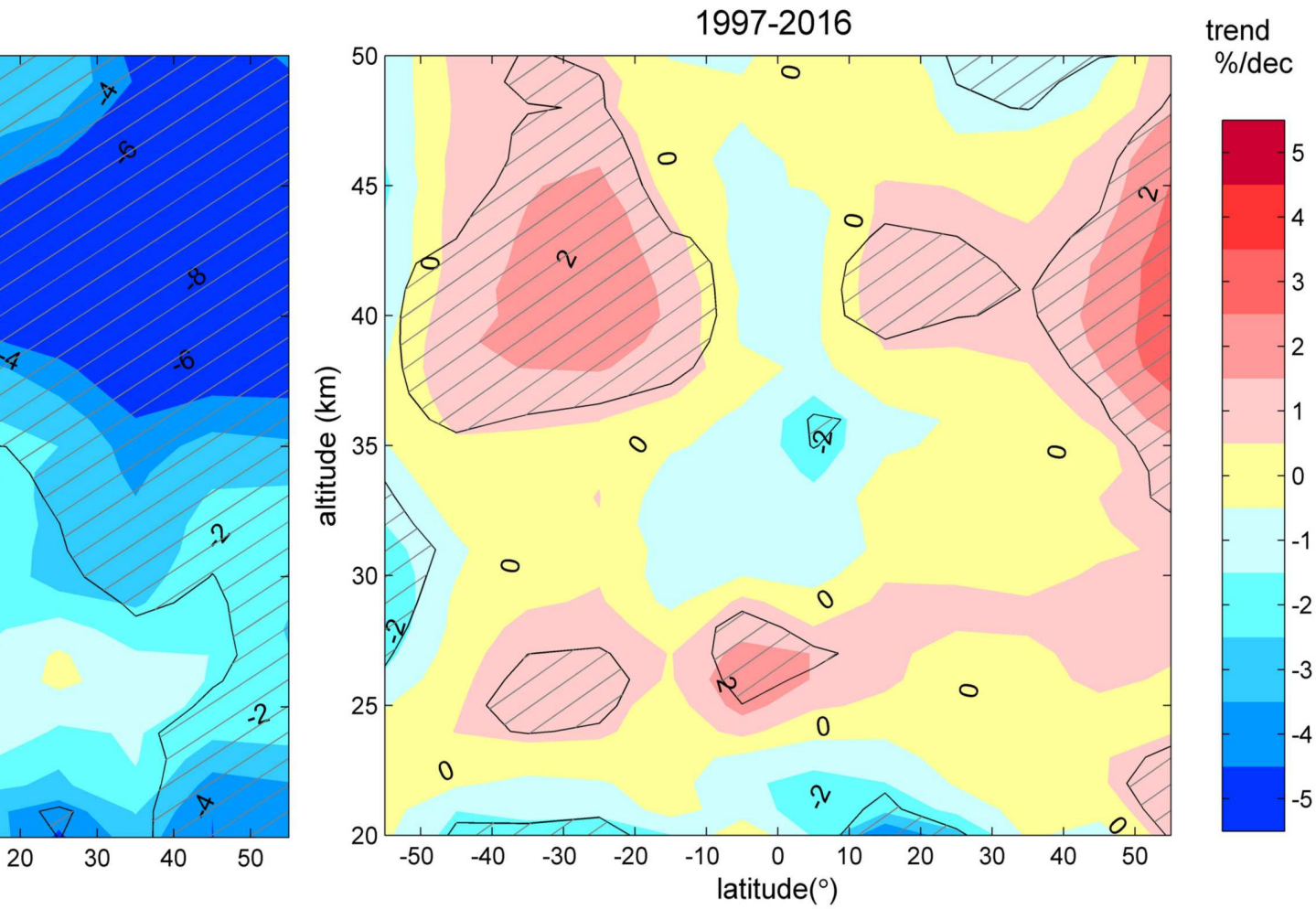
Climate scientists studying three decades of ozone measurements from seven satellites see a positive trend in global recovery thanks to international efforts to curb ozone-depleting substances.
The part of Earth's atmosphere with high concentrations of ozone gas protects life on Earth from the Sun's ultraviolet radiation. However, pollutants can break down ozone, thinning this layer and creating the infamous ozone hole.
The depletion of ozone in our atmosphere and subsequent increase in ultraviolet exposure causes skin cancer, cataracts and immune system damage in humans, and injures animals, plants and even microscopic phytoplankton.



Negative ozone trends in the upper stratosphere before 1997 and positive trends after 1997 are observed. Shaded areas show regions where the trends are statistically significant. [FMI]

Starting in the 1970s, ozone in the stratosphere – some 11–50 km above Earth's surface – began to decline worldwide. The largest drop was in the upper stratosphere, at 4–8% per decade.
The trend was interrupted following international agreements on the reduction of ozone-depleting substances and the first signs of ozone recovery were seen by satellites. Satellites provide good coverage but operate for a limited number of years. Meanwhile, climate scientists re-

The ozone layer protects life on Earth from ultraviolet radiation but it is also a powerful greenhouse gas. Satellites can provide measurements of atmospheric ozone and monitor distribution changes with the seasons. [Planetary Visions (credit: ESA/CCI Ozone and Aerosol teams/Planetary Visions)]



quire readings spanning 30 years or more for analysing trends accurately.

Ozone in particular varies depending on the season or solar activity, so decades are necessary to separate this natural variability from human-influenced change.

To tackle this, scientists working under ESA's Climate Change Initiative are harmonising measurements from different satellites to give us a long-term view of ozone variability.

The readings date back to 1995 for 'total columns' – meaning they show the total ozone of all layers of the atmosphere – and to 2001 for ozone profiles with high vertical resolution, meaning the separate layers can be identified.

The record relies on five satellite sensors that provide measurements with high vertical resolution. These include the ones on ESA's former Envisat mission, along with current information from Canada's SciSat and Sweden's Odin.

In a new development, measurements from NASA's Earth Radiation Budget Satellite and Suomi NPP satellite have been folded in, further extending coverage back to 1984. *"By merging the Climate Change Initiative's data with NASA's, we clearly see negative ozone trends in the upper atmosphere before 1997 and positive trends after,"* said Viktoria Sofieva, Senior Research Scientist at the Finnish Meteorological Institute.

"The upper stratospheric trends beyond the tropics are statistically significant and indicate an onset of ozone recovery." Ozone measurements with high vertical resolution are essential to identify these ozone trends.

The future Altius mission for ESA's Earth Watch initiative will provide continuing measurements for long-term climate monitoring. ■

Fake images in astronomy

by M. Ferrara et al.

2017 has emphasized the theme of fake news as if that phenomenon had never existed before, whereas it is ancient as humanity itself. Likewise remote is the origin of fake images, representations or altered interpretations of reality, which can be used for different purposes. This phenomenon is also widespread in the world of astronomy and often one is deceived by what is seen.

Not always fake images of astronomical nature are undoubtedly artworks like this background scene, presented in a documentary of the National Geographic magazine. Although the martian landscape represented here is decidedly realistic, we are certain that human beings have never reached the red planet, and it is therefore pure fantasy to represent them descended from a spaceship and engaged in a patrol. In this case, we are not in the presence of a false image or a tendentious interpretation of it, it is simply a science-fiction illustration, whose task is to give an idea of what might someday happen. To this typology of images also belong the representations of other planetary systems, collapsed stars and objects or phenomena never photographed from a close distance or in detail. Not always, however, the border

The starship Daedalus on Mars. The six astronauts travel to their new home in the rocket, which is based on technology just six years away. [National Geographic]

Strange views of the Sun, the Earth and the Moon

between true and false astronomical photographs is evident, and often in magazines and especially on the web, we find more or less fake images, which if not declared as such they can mislead less expert readers or visitors. Here we present some examples of fake images or artworks which at first sight appear realistic for the simple fact of containing real subjects, but which are instead photomontages.

Let's start with images that include the three most familiar subjects: the Sun, the Earth and the Moon. **At the top,** we see what should be a total eclipse of the Sun taken from high altitude (stratosphere or beyond). There are two elements that betray the falsity of the image: the shadow projected by the eclipse should be more rounded and the diamond ring around the Sun would be more than enough to delete the Milky Way. **Above** we find a full Moon that rises over a mountainous landscape and reflects in a lake. In addition to being unusually detailed, the lunar disk is oversized and its reflection in the water is too sharp when compared to that of the mountain.

Below, there is instead an overly large Earth 'seen' by astronauts on an Apollo mission. As Jim Lovell said (Apollo 8 and 13), from the

Moon it is enough to stretch out an arm and to raise the thumb upward to hide the Earth. In this case, the whole hand may not be enough.

Above, a pseudo-selfie of an astronaut. If the light that illuminates him is artificial, the background should definitely be darker. If the astronaut is illuminated by the Sun, one should not see the artificial lights on the ground. Regardless of this, the thickness of the atmosphere is excessive.

On the right, a rather unnatural view of the Moon photographed from high altitude (troposphere-stratosphere). In this case, the 'counterfeiter' has made several mistakes: the lunar disk is too large and its resolution is much lower than that of the terrestrial soil; moreover, the inclination of the Moon and its location in the sky compared to the daylight conditions are inconsistent with reality.

Below, an obvious false that wants to show the Earth as seen from the Moon. The surface in the foreground is very different from that of our satellite, and not even the alleged Earth shows clearly recognizable structures. Below, a suggestive scenario called 'sunset at the north pole with the Moon at the perigee'. It is actually a graphic elaboration of the astrophysics Inga Nielsen, 'stolen' and spread by others on the web as a photography. If it were a real image, the apparent dimensions of the Sun and the Moon would be comparable.

Above, an auroral ring as showed by many photographies from devices in orbit. But this is not very convincing, indeed, it is definitely false, and you can understand it from at least three important elements. The first is the absence of the atmosphere, indeed, despite about 1/3 of the globe is shown, there are no cloud formations and not even the typical illuminated border. The second suspicious element is the wrong position of the auroral ring, centred on the geographic pole rather than on the magnetic pole (in this period the two poles differ by about 400 km). The third suspicious element is the uniformity of the illumination of the ring, which, instead, should be brighter and more developed in the night hemisphere, and, on the contrary, less conspicuous in the hemisphere illuminated by the Sun.

Mars' strange landscapes and "animals"

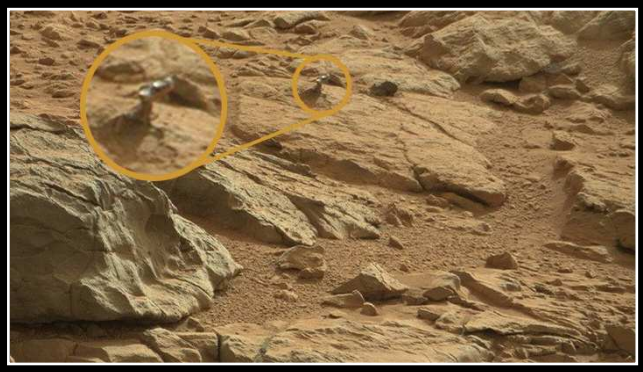


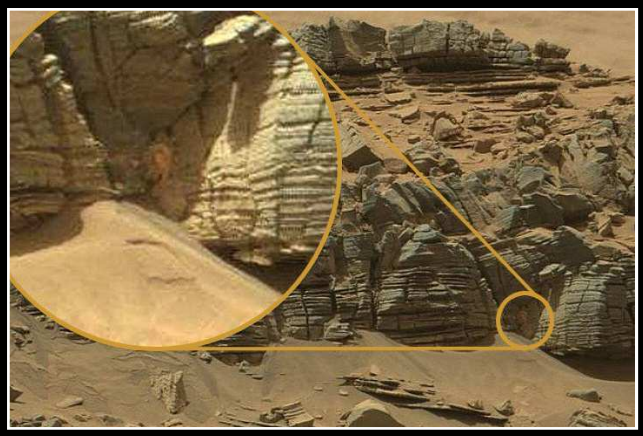
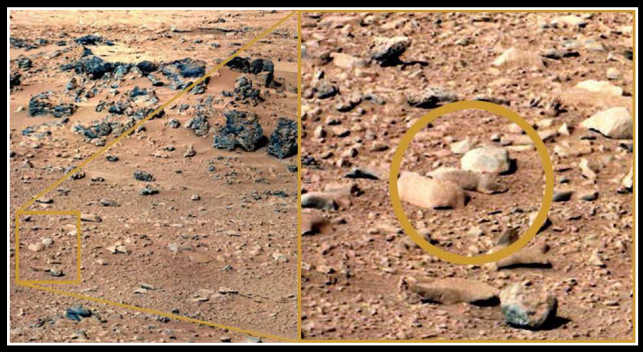


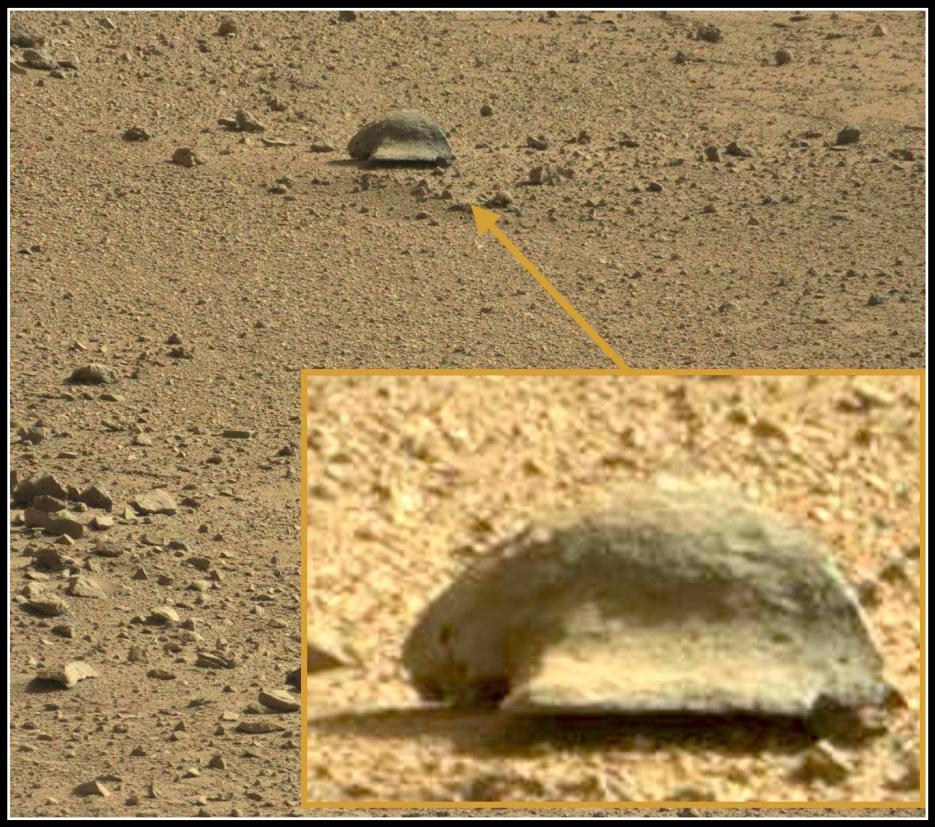


Speaking about fake images, we cannot not dedicate a section to Mars, the planet that for excellence lends itself to graphic fakes and imaginative interpretations of the immense database accumulated in almost half a century of automatic missions. Leaving aside the sci-fi trash, we have chosen here to represent two well-defined categories: wide martian landscapes graphically elaborated through an artistic touch, and small structures of the martian surface that resemble petrified animals and that just because of their appearance have produced unending speculations. The first category is well represented in the left column, composed of a series of artworks made by Kees Veenenbos on the basis of altimetric data provided by the Mars Orbiter Laser Altimeter (one of the five scientific instruments on board the Mars Global Surveyor probe, operating between 1997 and 2006) and processed using the Terragen software. In short, these are digital paintings and they should be considered as such, even if in some rare cases they seem a faithful representation of the reality.

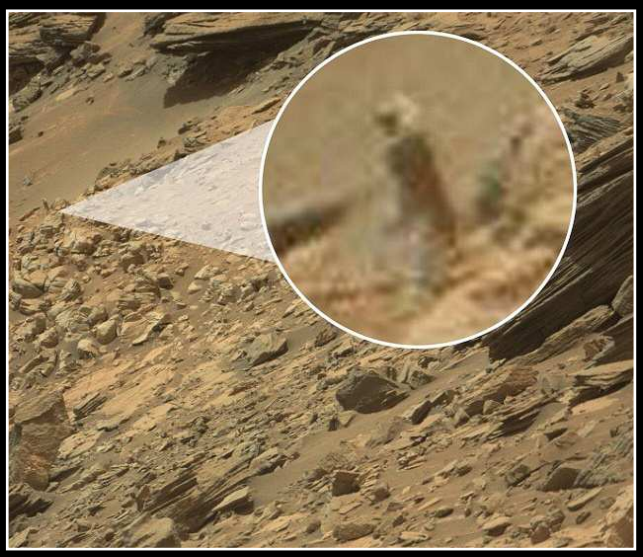
On the right and next page, we have instead a selection of improbable 'martian animals' found in the recesses of the surface of the red planet. From top to bottom we can 'recognize' a wary crab climbing on a rock, an iguana that turns towards the photographic device, a spider clinging to a group of sedimentary rocks, and finally a squirrel hidden between two stones.





Above we have a marmot watching over its territory, while at the side we see a carapace, what remains of a dead martian tortoise. In the two photographs below you can instead distinguish a toad and, on the right, a little — less defined — penguin. All these curious similarities are fun, but unfortunately, on the web, there are those who used them (and they are not few) to prove the existence of life on Mars. To believe and to affirm that these unusual rocky conformations are living or fossil animals only proves the ignorance of those who believe or affirm it. If such evolved forms of life exist or existed on Mars, we would have evidence of an entire biosphere, not just some isolated specimens. In addition, for billions of years, Mars has been deprived of an atmosphere thick enough to support highly evolved forms of life. Finally, why the alleged martian animals should be identical in shape and evolutionary stage to today's terrestrial animals?



Almost true nebular fakes

We conclude this brief digression on fake images with the deep sky, and in particular with a series of remarkable artworks realized by Jakob Schiller. They are excellent examples of how real images can be altered to create apparently natural subjects — as strange as they may seem — but that they are instead pure inventions of the author's imagination: ① a seal; ② a butterfly; ③ an anthropomorphic being; ④ a phoenix; ⑤ and ⑥ spectral faces; ⑦ an unusual fish.

At this point, it is clear that with regard to astronomical images it is not at all easy to distinguish the true from the false. On the web, there are thousands of examples of this type, many of which are shameless artefacts. But there are also many that effectively simulate reality. To be able to distinguish between a non-manipulated real photography (beyond reasonable processing), a reconstruction of a likely scenario (used to document) and a deliberately falsified image requires some attention. ■

TecnoSky

Via Fubine, 79 - Felizzano AL - ITALY - Tel. +39 0131772241
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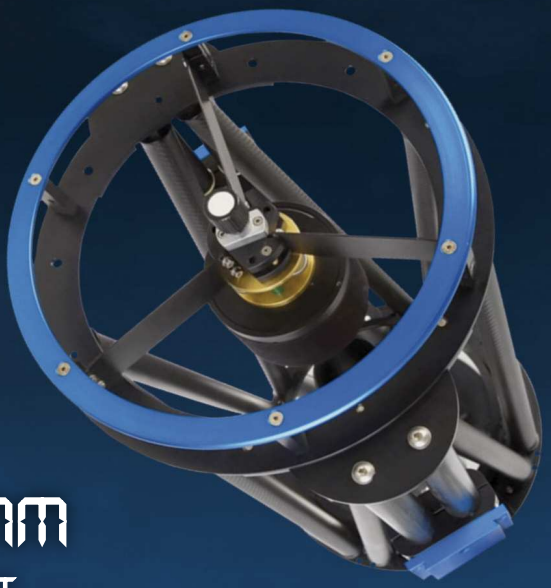

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